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J. A. UDDEN, Director

The Rustler Springs Sulphur Deposits

By
E. L. PORCH, Jr.

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The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas. Wm. B. Phillips, S. H. Worrell, and Drury McN. Phillips. University of Texas Bulletin No. 189, July, 1911. (Out of print.)

A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties. J. A. Udden, assisted by Drury McN. Phillips. University of Texas Bulletin No. 246, September, 1912. Price, 50 cents.

The Fuels Used in Texas. Wm. B. Phillips and S. H. Worrell. University of Texas Bulletin No. 307, December 22, 1913. Price, 40 cents.

The Deep Boring at Spur. J. A. Udden. University of Texas Bulletin No. 363, October 5, 1914. (Out of print.)

The Mineral Resources of Texas. Wm. B. Phillips. University of Texas Bulletin No. 365, October 15, 1914. Price, 50 cents.

Potash in the Texas Permian. J. A. Udden. University of Texas Bulletin No. 17, March 20, 1915. Price, 10 cents.

Geology and Underground Waters of the Northern Llano Estacado. Charles Laurence Baker. University of Texas Bulletin No. 57, October 10, 1915. Price, 25 cents. (Out of print.)

Road Materials of Texas. James P. Nash. University of Texas Bulletin No. 62, November 5, 1915. Price, 20 cents.

Origin of Texas Red Beds. Charles Laurence Baker. University of Texas Bulletin No. 29, May 20, 1916. Price, 5 cents.

Annual Report for the Year 1915, M. E. Stiles; Geological Maps in Texas, J. A. Udden. University of Texas Bulletin No. 35, June 20, 1916.

Review of the Geology of Texas (with map). J. A. Udden, C. L. Baker, Emil Böse. University of Texas Bulletin No. 44, 1916. Price, in paper cover, 70 cents; bound in cloth, 90 cents.

Contributions to the Knowledge of Richthofenia from the Permian of West Texas. Emil Böse. University of Texas Bulletin No. 55, October 1, 1916. Price, 15 cents.

The Thrall Oil Field. J. A. Udden, H. P. Bybee. University of Texas Bulletin No. 66, November 25, 1916. Price 40 cents.

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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FOREWORD.

Early in 1916, as a result of war conditions and the increased demand and higher price obtained for sulphur, the well-known but neglected sulphur deposits of West Texas attracted the attention of promoters and considerable activity was aroused in their development. Many promotion companies were organized, mainly in the North, and much stock was offered for sale both in northern states and in Texas. Inquiries regarding the deposits and the probability of their commercial development were received in this Bureau in such increasing numbers that it seemed desirable that the Bureau should make a detailed investigation of the situation in Culberson county and the adjoining region, and give to the public, in the form of a report from this office, some reliable information regarding the possibilities of the sulphur deposits there.

In accordance with this desire, Dr. Emil Böse and Mr. E. L. Porch, Jr., geologists of this Bureau, were sent out early in November to make the necessary investigation. After having looked over the field and advised with Mr. Porch as to the work to be done, Dr. Böse, according to plans agreed upon, returned to Austin and the work was left in the hands of Mr. Porch, who remained in the sulphur district until the latter part of December. Mr. Porch made a careful examination of as much of the field as the time would allow. The results of his work are presented in his carefully prepared report, which is herewith presented.

Taking a general view of the many and detailed descriptions given by Mr. Porch of the physical conditions indicated by the occurrence of the sulphur itself, and judging by his descriptions of the different materials in which the sulphur is contained, one would appear to be justified in supposing that the original source of the sulphur is to be looked for at considerable depth in the underlying sediments and is most probably to be found in deeplying Permian and Pennsylvanian shales containing iron pyrite and plentiful organic matter, undergoing slow heating, either from imperceptible tectonic movements or possibly from the existence of intrusive materials not yet cooled to the temperature

of the rocks into which they have been forced. Owing to such existing temperature at depth, hydrogen sulphide and no doubt also other gases, are, perhaps, slowly migrating through the overlying rocks up to the surface and are quietly and slowly escaping at a great number of places in the region. It would be natural that gas escaping in this manner should follow the most pervious places in the underlying rocks. It would also be natural that accumulations of sulphur in the surface material should be found to be generally dispersed surficially and that they should be found near the most pervious passages in the greatest abundance. The sulphur in the surface materials and in such "chimneys" would represent that part of the escaping gases which has been oxidized and reduced before escaping into the atmosphere. The differences in the color of the materials in which the sulphur is now held apparently are due to atmospheric reactions of oxidation and weathering. The darkest matrix, usually lying deepest, as is so clearly set forth by Mr. Porch in his descriptions, probably owes its dark color to the presence of organic material or to finely disseminated iron sulphide, formed by the escaping gas. The brown and reddish matrix, which is found commingled with the darker material, but which in general overlies the latter, probably owes its color to the oxidation of the iron sulphide present in the dark underlying material, and is merely a changed condition of this material, caused by the more ready access of the atmosphere to its uppermost zone. The gypsite, which forms the surface material, is no doubt a true mantle rock distributed by the agency of wind and water, being a mixture not only of transported material on the surface, but also of disintegrated brown and dark sulphur matrix in place, and of precipitates from the evaporation of ground moisture, usually known as caliche.

If we take this view of the origin of these sulphur deposits we have a ready explanation of the quite general distribution of the sulphur in the surface materials. We can also expect that while the surficial material may be found to contain some sulphur almost everywhere, more or less sulphur will also be found extending down to considerable depths in places where the rock has been sufficiently porous to afford ready escape of the gases. This deeper sulphur would form what have been

called in other parts of the world, sulphur chimneys, and some such deposits should also be expected to exist in this field, although explorations up to this time may not have demonstrated their presence.

J. A. UDDEN.

Austin, Texas.
May, 1917.

INTRODUCTION.

The sulphur deposits considered in this bulletin are located, with three exceptions in the northeastern part of Culberson County, formerly part of El Paso County; the exceptions noted being in Reeves County, about sixteen miles northwest of Toyah. All of the other deposits lie in the area included between latitude 31°-30′ to 32°, and longitude 104° to 104°-30′. Their distances from Orla, the nearest railroad station on the Pecos Valley and Northeastern Railroad, which is about forty-one miles northwest of Pecos, vary from fifteen to forty-five miles, by automobile road. From Carlsbad, New Mexico, it is fifty miles to the nearest sulphur deposit.

The existence of sulphur in this section has been known since 1854, when it was noticed in the bed of Delaware Creek, by William P. Blake, geologist for an expedition sent out by the United States War Department under the command of Capt. John Pope.

A sample taken at the Delaware Springs contained 18.28 per cent. of free sulphur and samples of water from the springs were found to contain, among other things, considerable sodium sulphide.*

Dr. Geo. G. Shumard, under date of Sept. 25, 1855, in "A Partial Report on the Geology of West Texas," Part II, Chapter V, p. 92, mentions the spring at the head of Delaware Creek as containing much hydrogen sulphide. In a paper by W. von Streeruwitz, on "Geology of Trans-Pecos Texas; Preliminary Statement," First Ann. Report, Geological Survey of Texas, 1889, p. 226, sulphur is mentioned as among the list of minerals noted in this region.

In the Third Annual Report of the Geological Survey of Texas, 1891, W. F. Cummins states on page 165 of "A Report on the Geography, Topography, and Geology of the Llano Estacado or Staked Plains" that while camped at Castile Spring, they spent two days in search of a reported bed of sulphur, but

*Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean. U. S. War Department, 1853-4, Vol. II, cited in University of Texas Mineray Survey, Bulletin No. 2; Report of Progress for 1901. Sulphur, Oil, and Quicksilver in Trans-Pecos Texas, pp. 27-42.

were unable to locate same. On page 212, he speaks of a spring, highly impregnated with sulphur, and containing hydrogen sulphide, at the head of Delaware Creek. On page 221, he speaks of the flowing well at Toyah, 834 feet deep, which is reported as yielding water impregnated with sulphur and common salt.

Prior to 1896, reports were made on this district by Dr. Eugene A. Smith, Director of the Alabama Geological Survey, and by Mr. John E. Rothwell of Denver, Colorado. Dr. Smith wrote a short account of some of the deposits for "Science." This was published in Vol. III of that journal, No. 70, May 1, 1896.

The whole sulphur situation, in so far as it was known up to that time, was well summarized by Dr. Wm. B. Phillips in the University of Texas Mineral Survey Bulletin No. 2, "Report of Progress for 1901; Sulphur, Oil and Quicksilver in Trans-Pecos Texas," pages 27-42. This report, unfortunately, has been out of print for a number of years. It contains the article written by Dr. Smith, for "Science," and also a report on the whole area, prepared especially for the Mineral Survey by Mr. E. M. Skeats of El Paso, Texas. Mr. Skeats was the first to notice the presence of free sulphuric acid in the waters of this region.

In 1903, Mr. Geo. B. Richardson, of the United States Geological Survey, acting in co-operation with the University of Texas Mineral Survey, did some work on these deposits in connection with the general geologic mapping of this region. The results of his work were published in the University of Texas Mineral Survey Bulletin No. 9, November, 1904, "Report of a Reconnaissance in Trans-Pecos Texas, North of the Texas and Pacific Railway," pages 68-71, by Geo. Burr Richardson.

In the Manufacturers' Record, of Baltimore, Md., December 7, 1916, there appeared an article on "The Sulphur Situation in Culberson County," by Dr. Wm. B. Phillips.

In addition to the reports above enumerated, a number of private reports have been made on this district. Several of these have also been consulted in the preparation of this paper.

The Present Study.

In all, about five and a half weeks were spent in examining this district for the present report. This work was done in the fall of 1916. All of the deposits where work was being done, or

where considerable work had been done in the past, were studied in detail, and all other sulphur occurrences that could be located were visited and examined.

The deposits were examined with special reference to their physical characteristics, and to their geologic relations, and notes were taken on their relations to structure wherever this could be ascertained.

Samples were taken from the various deposits, with the view of securing some general information on the sulphur content of the deposits examined.

The desirability of figuring tonnages where much work had been done was considered, but it was found impracticable, on account of insufficient development, to accomplish any results of value in this direction.

All points that might have any bearing on the possible origin of the sulphur were also carefully looked into, and considered.

Acknowledgments.

The writer wishes to acknowledge the courtesies shown him during the examination of the sulphur deposits, both by the operators and by the residents of the district. Everyone showed the greatest willingness to assist in every way possible, and records and special information about the properties were turned over unstintingly.

He is especially indebted to Mr. F. W. Felch, Mr. C. R. Troxel, Mr. Carr, Dr. Gustav Grossman, Mr. Abernathy, Mr. W. A. Doyle, Mr. M. S. Blackburn, Mr. Voight, Mr. Snell, Mr. Barriger, Mr. Vergil Albritton, Mr. J. A. Martin, Jr., Citizens State Bank of Toyah, Mr. Cooksey, and Mr. Hollebeke. Dr. Wm. B. Phillips of Austin furnished many data on the district and permitted the inspection of several unpublished reports on the district, which he possesses. Mr. C. C. Dana of Amarillo very kindly loaned that part of the files of the Panhandle and Santa Fe Railroad dealing with the sulphur deposits of this district. Dr. Emil Böse was present during the first two weeks of the field work, and gave much helpful advice, based on his wide knowledge of other sulphur districts.

The writer's thanks are especially due to Dr. J. A. Udden for the kindly suggestions made while reviewing the bulletin, and for the revision of several of its parts.

GEOLOGY.

The whole sulphur area is a plain sloping gently to the east, with the Rustler Hills, which trend slightly northeast-southwest, rising some two hundred and fifty feet above the general level of the gypsum plain on the west and the gypsum and alluvial flats on the east. The area is thus divided into three unequal parts; a larger relatively flat plain on the west, a hilly central belt, and a smaller part of flat plain to the east. The term "plain" must be considered advisedly, for we find the land to have many low hills, mesas, and draws, or drainage channels. Some scattered hills in the western side of the area are as high as, or higher than, the main Rustler Hills.

The beds exposed in the area under consideration belong to the following geologic divisions, starting with the youngest:

System	Epoch	Series
Quaternary		Recent
		Pleistocene
Cretaceous	Comanchean	
Permo-carboniferous or Permian		Rustler Formation
		Castile Formation
Permo-carboniferous		Delaware Formation

Structure.

A consideration of the three lowest and most important formations outcropping in this area shows that the general structure is that of a monocline dipping gently to the northeast. Within this monocline, however, there are many local variations of dip forming apparently small and irregular anticlines, synclines, and domes in many places.

These secondary structures are usually small, and seem to be confined to the Castile and Rustler Formations, as the Delaware Formation, where observed, has quite a uniform and persistent dip.

It is believed that the majority of these structures is caused by local effects, probably by slumping of the upper beds, due

to the solution of the supporting gypsum beds below, or to the crumpling of the beds due to the swelling of the underlying anhydrite as it is converted to gypsum. However, it is impossible to say without a much more detailed study, whether some of these structures may not be due to real earth movements.

Deep Explorations.

The underlying rocks in this region are known only from some well records and from examinations which have been made of cuttings from two deep borings. Dr. J. A. Udden has published descriptions of cuttings from Troxel Well No. 1, some 400 feet deep. These descriptions show the presence of gypsum, and of "red beds" at several depths down to the bottom of the boring.* In some of these samples, many foraminifera of decidedly Cretaceous aspect were noted. Dr. Udden has suggested that these may represent fillings of Comanchean material in caverns in the Permian strata of limestone and gypsum. The actual existence of these fossils has lately been corroborated by their occurrence also in the much deeper Troxel Well No. 2, drilled near the first well, as will be seen in the descriptions below. In this well the foraminifera were found about 400 feet below their place in the first well.

DESCRIPTION OF SAMPLES FROM TROXEL WELL NO. 2.

Rustler Springs, Culberson County, Texas. Located near the south line of Section 24, Block 110, Public School Lands, close to Troxel No. 1. Drilled in 1915. Descriptions by E. L. Porch, Jr., and J. A. Udden.

	Feet
Red sandy clay	85
Greenish gray clay and some red clay. Some fragments of gray, compact dolomite	150
Dark gray and brownish gray limestone of very compact texture. Gypsum, quartz grains, fragments of chert and other quartz, and pyrite noted	235
Gray dolomite of very fine texture. Pyrite, gypsum, rounded clear quartz grains and quartz crystals noted	240

*Am. Jour. Sci., Vol. XL, August, 1915. The Age of the Castile Gypsum and the Rustler Springs Formation, by J. A Udden.

Feet

Dark gray dolomite of fine texture. Effervescence in acid is extremely slow. With this is some marl. Fragments of gypsum, many. There are some rounded grains of quartz and some quartz crystals. Much pyrite. No bituminous fumes noted.... 250

Gray and brownish gray dolomite of fine texture. Considerable pyrite noted. Many rounded sand grains of clear quartz noted. There are also crystals of quartz. Label says: "Bottom of lime"..... 250

White gypsum, of moderately coarse crystalline texture. The sample contains some double pyramidal crystals of quartz, the largest 0.75 mm. in length..... 255

Mostly gypsum, with some anhydrite, white and gray, mostly moderately coarsely crystalline..... 350

Mostly gray and brownish dark gray dolomite of fine compact texture. In thin section it is seen to contain some anhydrite and is impregnated with pyrite, which occurs in exceedingly fine particles. The sample contains coarse rounded quartz sand and fragments of quartz pebbles. Much anhydrite present..... 405

Compact gray dolomite and white anhydrite. Bright yellow pyrite noted 450

Anyhdrite and gray compact dolomite. Bright yellow pyrite and fragments of quartz noted..... 500

White and gray anhydrite..... 515

White anhydrite, with some rounded quartz sand grains. Pyrite noted 540

White anhydrite 545

White and gray anhydrite, some quartz sand, fragments of gray flint, crystals of gypsum, and pyrite.....550-555

Anhydrite with some sand, some pyrite, and considerable chert, which seems to have been in the form of pebbles. Most of the chert is dark.....555-560

White anhydrite. Some flint present..... 600

White and gray anhydrite. Some quartz, some pyrite, and some flint present 625

White anhydrite, with a few particles of calcareous material..... 630

Gray dolomitic limestone containing pyrite, anhydrite and sand... 630

Light gray dolomitic limestone containing anhydrite, pyrite and sand. Another sample consists of anhydrite..... 650

Light gray anhydrite containing sand, pyrite, and a black mineral. Gave off a faint odor of bitumen when heated. An Endothyra was noted 680

Anhydrite containing a little sand..... 715

Anhydrite containing considerable calcareous material and some sand. On heating, a faint odor of bitumen was given off and a little sulphur deposited in the tube. Label says: "Gas"..... 735

Feet

Gray sandy limestone containing pyrite, fragments of pebbles of gray and dark chert, and gypsum. Endothyra noted. Gave off the odor of bitumen on heating..... 740

Gray limestone containing chert, anhydrite, sand and pyrites. On heating, gave off faint odor of bitumen, and a little sulphur was deposited in the tube. Endothyra and Textularia noted. Label says: "Some gas"..... 745

Gray limestone containing sand, most of which is below ⅛ mm. in diameter. Chert, anhydrite, and pyrite. On heating, a little oil distilled off..... 757

Light gray dolomitic limestone containing sand, fragments of chert pebbles, pyrite and anhydrite. Gave off odor of bitumen on being heated 795

Gray anhydrite, quartz sand, some calcareous material, and some dark chert grains..... 800

Anhydrite, white, gray and yellow..... 810

Anhydrite, and very dark limestone..... 822

Mostly white and gray anhydrite. Some very dark limestone, some sand and some fragments of greenish shaly rock..... 828

Yellowish and dark limestone with sand and very fine gravel. Pyrite and anhydrite noted. Some foraminifera like a Textularia with perforate walls was observed, and an Anomalina, well preserved 837

Limestone and anhydrite, both in very dark and in very light gray shades. Some sand present. Foraminifera of the types of Globigerina and Textularia quite common..... 843

Dark gray and brown lime rock, some black chert, sand, and some anhydrite. Pyrite noted..... 843?

White and dark anhydrite and some limestone. Sand and pyrite noted. Textularia present..... 850

Anhydrite, mostly white, and some dolomite. Globigerina, Textularia and a foraminifer like Anomalina noted..... 857

Like the preceding. Pyrite noted..... 857

Light gray limestone containing chert, sand, pyrite and considerable anhydrite. Gave off the odor of bitumen on being heated. Endothyra noted. Label says: "Little gas and oil".....940-943

Anhydrite containing calcareous material and a little sand. Some sulphur was deposited in the tube on heating.....1030

Light gray limestone containing anhydrite, and pyrite. Upon being heated, a little sulphur was deposited in the tube, and a faint odor of bitumen was given off. An Endothyra was noted. Label says: "Gas and little oil".....1152-1154

Gray dolomitic limestone containing considerable sand, most of which is below ⅛ mm. in diameter, and a black mineral, probably chert. Some oil was distilled off, on the material being heated 1449

Feet

Dark gray limestone containing anhydrite, pyrite, sand, and a black mineral, probably chert. Considerable oil was distilled off on heating the material....1942

Gray cherty limestone containing sand and anhydrite. Some oil was distilled off on heating the material....1956

Gray, argillaceous, dolomitic sandstone containing a considerable quantity of black mineral, probably chert. Most of the sand is below ⅛ mm. in size. Considerable oil was distilled off on heating the material....1962

Gray, dolomitic limestone containing black fragments (probably carbonaceous material), pyrite, sand, chert and anhydrite. A little oil distilled off on heating....1982

Gray sandy marl containing pyrite and a black mineral. Considerable oil was distilled off on heating....1988

Gray limestone containing considerable chert and sand. Some oil distilled off on heating....1994

Dolomitic limestone containing pyrite and a black mineral. Most of the sand is below ⅛ mm. in diameter. Gave off a little oil on heating....2006

Sandy dolomite containing pyrite. Considerable oil distilled off on heating....2010

Sand and clay containing a black mineral, probably chert, a little pyrite, and very little calcareous material. Gave off considerable oil on heating. Most of the sand is below ⅛ mm. in diameter. An Endothyra(?) was noted....2018

Brown limestone containing pyrite, anhydrite and sand. Some sulphur was deposited in the tube upon heating....2028

Brown limestone, containing some considerable sand, most of it below ⅛ mm. in diameter, and a little chert. On heating, it gave off the odor of bitumen. An Endothyra(?) was noted....2035

Argillaceous dolomitic sandstone containing anhydrite and pyrite. The majority of the sand grains are smaller than ⅛ mm. Some oil was distilled off on heating....2041

Gray, argillaceous, dolomitic sandstone, containing a black mineral, probably chert. Some oil was given off on heating....2045

Gray, sandy, dolomitic limestone, containing a little anhydrite, pyrite and bitumen. A little oil was distilled off on heating. Water at 2045 feet....2052

Gray, calcareous sandstone containing chert, pyrites, and a green mineral. Most of the sand is below ⅛ mm. Endothyra was noted. Some oil was distilled off on heating....2066

Gray, sandy dolomitic limestone containing pyrite, chert, and a little anhydrite. Gave off odor of bitumen on heating.... 2138

Gray, sandy limestone. Most of the sand is below ⅛ mm. Some oil distilled off on heating....2190

	Feet
Blue-gray, sandy, dolomitic limestone; a little oil distilled off on heating	2197
Gray limestone containing some sand, most of which is below ⅛ mm. in diameter. Some oil was distilled on heating	2204
Gray, sandy, dolomitic limestone containing a little chert(?). Gave off a slight odor of bitumen on heating	2230
Gray, dolomitic limestone containing considerable sand, most of which is below ⅛ mm. in diameter, and a black mineral, fragmentary	2236

The deepest exploration in the region is the Huling-Ross Well No. 1 on the west half of Section 16, Block 59, in Reeves County. This extends to a depth of 4100 feet. In this boring, shale, gypsum, sand, some limestone, and red clay are reported from the uppermost thousand feet, and gypsum, "red beds" and sand are reported for the next thousand feet. The beds below this are known from samples and their character has been summarized as below:*

"Twenty-three samples representing the rocks penetrated from 2000 to 3000 feet below the surface, consist of anhydrite, in the main, intimately associated with more or less dolomite, and having mostly a thinly laminated structure, such as is seen in parts of the Guadalupian formation. Some fragments showed that this rock has in places been brecciated.

"At 2700 feet there is some nearly pure dolomite. Near 2800 feet there is a gray limestone containing some foraminifera and fragments of small shells and other fossils. In this part of the section the rock is otherwise uniform in character. Below this depth the samples from 3050 to 4115 feet consist of a rock which may be described as dolomite containing more or less fine sand, silt and clayey material. The range of variation in the composition of this rock is from nearly pure dolomite, containing only a small amount of siliceous material, to pure sand, as at 3100, 3150, 3400, and 3500 feet below the surface. At various depths, this rock has been impregnated with much bituminous material, so as to be black. Much of the other sandy dolomite is to a less degree impregnated with hydrocarbons, so that nearly all the samples from this part of the well will yield bituminous fumes and even drops of oil when heated in a closed tube.

"A mixed sample of this black rock taken from five different

*Bulletin of the University of Texas, Bureau of Economic Geology and Technology, No. 17, March 20, 1915. Potash in the Texas Permian, by J. A. Udden, pp. 46, 47.

depths was distilled to determine the hydrocarbon content. It was found to contain 14.2 per cent. of volatile combustible hydrocarbons. This includes an amount of oil equivalent to 2.4 gallons per ton of the rock."

The lower part of this boring undoubtedly extends a considerable distance into the Delaware formation.

The Delaware Formation.

The age of the Delaware Mountain beds is known to be lower and upper Permo-Carboniferous. They were not examined in any great detail for this investigation, just enough work having been done to try to determine, if possible, their relation to the overlying gypsum beds. The area examined lies just north and south of the Delaware Creek. As seen here, the beds are predominantly sandstone, usually somewhat calcareous. Near the top there are occasional layers of shales and limestones, some of the shale being very much indurated and highly carbonaceous.

From the Delaware Mountains to the gypsum plains, the country is gently rolling, with many hills scattered here and there, some of them flat-topped, due to a capping of limestone, or perhaps exhibiting what appears to be the typical form of erosion hills of the Delaware Formation where a hard capping is lacking: fairly well-rounded hills with steep sides, with occasional vertical cliffs where more massive or more resistant beds happen to be. Some of the hills are fair examples of wind-carving.

At a point some one mile east of Delaware Springs, a cliff on the Delaware Creek, nearly a hundred feet high, shows what is either the topmost beds of the Delaware or the lowest beds of the Castile Formation. Plate 8a. There are about twenty feet of thin-banded bituminous limestone, cavernous in places. Below this, down to a few feet above the water level, there are alternating beds of impure limestone and shale, some of the shales about in the middle of the section being somewhat purplish red in color. As a rule, the shaly layers have resisted erosion less than the limestone and are cut in deeper than this, leaving the top layers as an overhanging cliff in places.

A yellowish, rather fine-grained, sandstone begins a few feet

above the water level. This is like a great part of the sandstone noted in the Delaware. This sandstone, traced up the river, varies from thin-bedded to massive, and is characterized by many nodules. These were originally pyrite, but are now weathered, where exposed, to limonite, although usually showing some pyrite in the center when broken into.

In December, 1916, the uppermost flowing water in the Delaware Creek was a small sulphur spring about one mile east of where the country road crosses the river. This water contains sulphur in a finely divided state, and issues at or near the contact between a dark blue indurated carbonaceous shale and an overlying sandstone. Several hundred feet of this formation occur in the lower part of Troxel's well No. 2.

From the exposures seen it was impossible to tell positively whether the Castile Formation lies conformably or unconformably on the Delaware, but they appear conformable. Geo. B. Richardson thinks that the two formations are unconformable.*

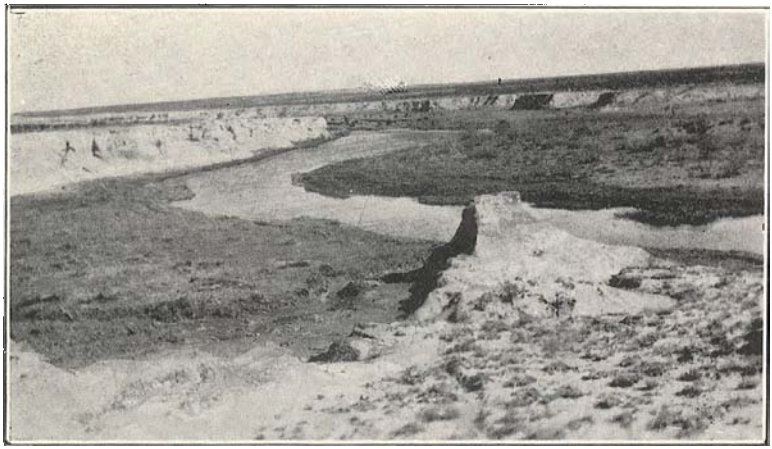
Castile Formation.

Although the greater part of it is covered with gypsite or gypsiferous soil, this formation as exposed may be roughly divided into two belts, an eastern and a western. The western belt is characterized by thin-banded gypsum, folded and contorted, and by gypsum hills, capped by more resistant layers of finely laminated bituminous limestone. These hills sometimes contain a limestone core.** White massive gypsum also occurs here. The eastern section is characterized by massive beds of white gypsum, while some of the "red beds" exposed east of the Rustler Hills may probably be included here, as in places there is typical Castile both below and above them. The Castile Formation probably reaches a thickness of approximately 2000 feet in the Huling-Ross Well No. 1, while in the Troxel Well No. 2 the thickness is probably between 1500 and 1800 feet.

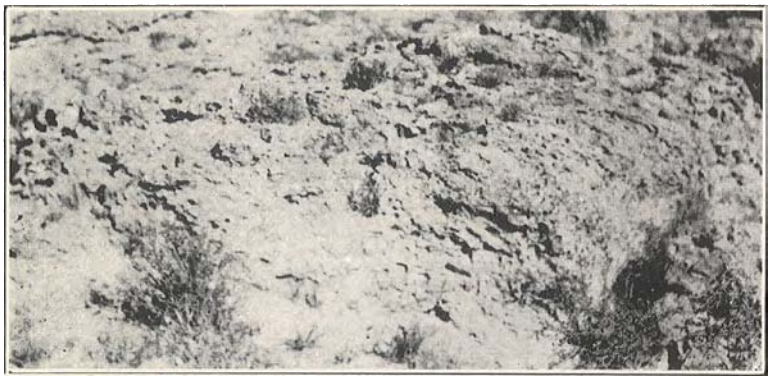
In exposures, the gypsum is very cavernous, and it is impos-

*The University of Texas Mineral Survey, Bulletin No. 9, November, 1904; Report of a Reconnaissance in Trans-Pecos Texas, north of the Texas and Pacific Railway, by G. B. Richardson; page 43.

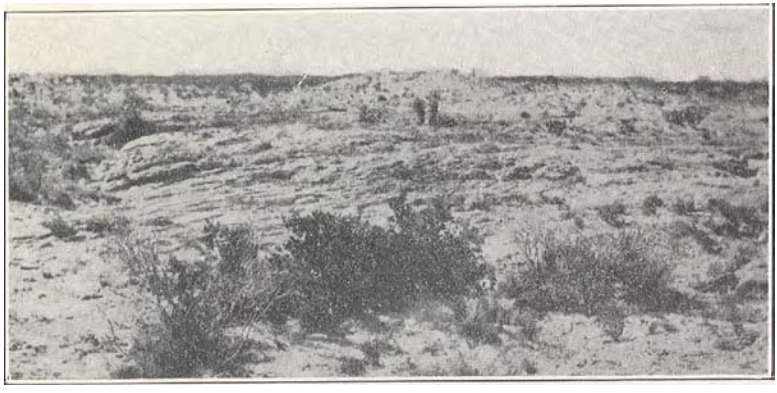
**See description of the Grant Property.



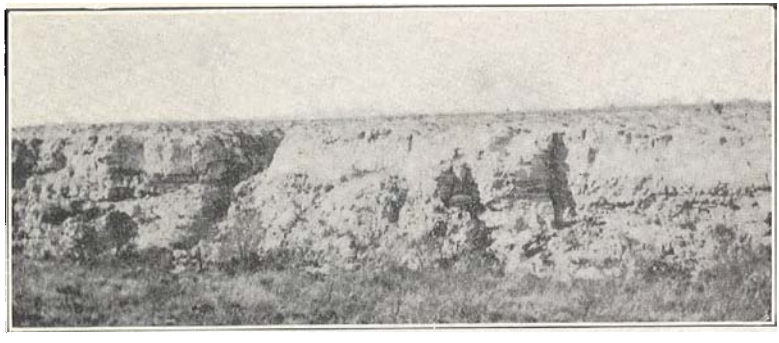
a Maverick Springs, looking northeast. Erosion extending into the Castile Formation. Red bed materials show on both sides of this draw, the small hill in the foreground being partly composed of this material.



b. Characteristically weathered and cavernous dolomite (Rustler?) in the Virginia Draw near the Dot Prospect. The hill in the background is covered with gypsite.



a. Dip of the bed rock (limestone or limy dolomite) in the Virginia Draw, near the Dot Prospect. Bank above capped by gypsite. Looking west. Rustler hills in the distance.



b. Gypsum beds changing upward into gypsite in the Virginia Draw near the Dot Prospect. The gypsum beds are very much broken up.

sible to work out any real structure in it. In places, it looks as if it had been derived from limestone. Some sulphur occurs in the solid gypsum, but it has not been found in any considerable quantity, the most sulphur being in material of a later age.

Rustler Formation.

The Rustler Hills in this area run practically from north to south, and form a wide and low dissected ridge, being cut through by many draws, running both east-west and north-south. These leave a number of isolated hills and ridges by reason of having cut down through the Rustler to the underlying gypsum. The greatest aggregate width of the exposed belt of the Rustler Formation is some seven or eight miles.

The greatest thickness of this formation appears to be less than 250 feet. It consists typically of a brown gray dolomite or dolomitic limestone, containing, as seen at the extreme eastern and western exposures, east and west of the Michigan property, small white, button-like, calcareous nodules or inclusions, and a peculiar circular pitting, very uniform, the small holes sometimes being filled with calcareous material. On the hills overlooking the Michigan property, there were noticed many weathered blocks of what was apparently ordinary dolomite, yet seeming to contain a large number of angular fragments or dolomitic breccias. East of Troxel's well, this formation contains some beds of sandstone and conglomerate, and also of pink dolomite. The pebbles of the conglomerate are largely composed of flint, although an occasional one of dolomite may be seen. In places, however, there is considerable dolomitic conglomerate. The flint pebbles appear identical with those now so wide-spread over this district, and it is very likely that these are derived from former extensions of the Rustler, both east and west, which have long since been removed.

The Rustler in places is quite badly broken down, probably due to the slumping of the gypsum beneath.

On the eastern side, in an area of about one square mile, dips were noticed varying from southeast to northwest, the general direction of the dips appearing to be to the northeast. In a distance of about one thousand feet east of Troxel's well, start-

ing near the well, dips having the following directions were noted: east, south, west(?), east, almost south, and west (quite persistent), the last three occurring very close together. West of the well about five hundred feet there is a strong dip to the west. The Rustler is very thin at this point.

From a study of the alternating beds in the logs of the two deep wells drilled in this district, it is believed that this formation may be a large lens, in and near the top of the Castile Gypsum, from which the overlying gypsum has been removed by erosion.

Red Beds.

Besides those beds described near Maverick Springs, some of which are in the gypsum, and some of possibly later origin, there is a patch of "red bed" material near the Toyah-Michigan road about twenty-seven miles from Toyah. It is not known just where this belongs, stratigraphically.

Cretaceous.

There are no known beds of this age in the immediate vicinity of the sulphur deposits, in Culberson County, unless it be some of the conglomerates. Beds of this age occur just east of Cottonwood Draw and near the Huling-Ross deep well. Several Comanchean grypheas were found in a conglomerate about two miles northeast of Toyah, showing the proximity of the Comanchean at the time this conglomerate was made.

Quarternary.

To this age belongs most of the surface covering east of the Rustler Hills, and probably most of the gypsite west of them. This is a gypsiferous material, resulting from the disintegration of the original formation. Within the area covered, these deposits consist of the gypsite mentioned, conglomeratic material containing flint pebbles, clays, sands and some caliche. The flint and the dolomitic conglomerates may belong here or they may be older. The same may be said with regard to most

of the sulphur, for although some of this does occur in the unaltered gypsum, it is present as a secondary ingredient. Most of it occurs in the altered and younger deposits.

Both east and west of the Rustler Hills, there are many flint pebbles mixed with the soil, plentiful enough in places to form local conglomerates. Some pebbles of volcanic material were noticed a few miles east of the Rustler Hills, but none was noticed west of them. These pebbles were probably derived from the Davis Mountains.

A patch of stream bed or river conglomerate occurs in the bed of the Delaware Creek and in the small branches running into this stream, about four miles east of Delaware Spring. This persists for about a quarter of a mile, and is probably recent in origin. It shows the characteristics of a river conglomerate, being very irregularly bedded, with lenses of poorly consolidated sand. It appears to be fairly resistant, and is being cut into by the Delaware Creek. In one place a mushroom-shaped rock was noticed. This conglomerate consists mainly of rounded pebbles of dark blue, fine-grained, hard, thin-bedded limestone or dolomitic limestone, and consolidated sand, the cementing material being largely calcareous. Both pebbles and sand appear to be derived from the Delaware Mountain formation. One piece of the blue limestone noted had a cup coral, and another piece contained many Fusulina elongata(?).

DESCRIPTIONS OF SULPHUR DEPOSITS.

Sulphur occurs in a number of localities in an oval area extending from northwest to southeast, as indicated on Plate 9. This area has a length of about 46 miles and a width of about 22 miles. The bedrock consists largely of the Castile gypsum formation. In the southeast end some of the Comanchean outcrops are seen in close proximity to, if not directly underlying, the sulphur.

The larger part of the time spent in the field was given to a close examination of the individual sulphur deposits so far known from explorations which have been made at different times during the last thirty years. I shall here present descriptions of these occurrences, beginning with the localities farthest southeast and proceeding northwestward.

*Pit in Center of Section 34, Block 70.**

This pit shows dark colored, porous and cavernous, soft rock, containing much finely crystallized selenite and a fair sprinkling of minutely crystallized sulphur deposited with the selenite. The material in the pit had a distinct disagreeable odor, suggesting gaseous emanations.

*Pit in Southeast Corner of Section 13, Block 70.**

An eight-foot pit, showing one and a half feet of surface soil; below this a pure white clay like deposit containing considerable gypsum, stained red with iron in the bottom of the pit. On analysis this white clay-like substance showed considerable sulphur. (See p. 61 below.)

The Johnson Prospect.

This prospect represents, so far as is known, the eastern limit of the sulphur deposits. It is located in Section 8, Block 59, Reeves County, and is about one and one-half miles northwest

*Information on these two locations was furnished by Dr. J. A. Udden.

of the Huling-Ross deep well. There are a number of wells, drilled for oil, on the east, southeast, and south of this property at distances varying from one-third to three-quarters of a mile. Several of these, shallow wells, have produced small quantities of a heavy oil. Oil is standing about thirty-five feet below the surface in two of these shallow wells located in the southwest corner of Section 9.

Recent deposits resembling those found as a veneer over the Toyah basin, cover the surface in this vicinity. They consist of gravel, sand, gypsum, caliche and clay. The sulphur deposit is located in a depression, and the sulphur shows at the surface in many places. Two pits, each about ten feet deep, were put down on this property about a year and a half ago. At present, there are several feet of water standing in these pits, through which considerable gas is bubbling. Little craters, perhaps a quarter inch in diameter, through which gas has bubbled, were noted near one of the pits, and around these craters, thin layers of greenish-yellow substance, perhaps alum, had been formed. Fragments of brittle blue flint are present in some abundance.

The sulphur has been deposited, along with considerable selenite, in small cavities and cracks. There are to be found several varieties of sulphur, such as a yellow variety, both amorphous and crystalline; an amorphous variety, at times showing concentric banded structure as if it had grown around a nucleus; and also a drab brown, irregularly thin-banded clay-like sulphur, which is quite lustrous, when it is evenly cut.

The containing rock is gypsum, containing silica. Some of this may have originally been limestone, now altered to gypsum by the action of sulphuric acid. In fact, the blue flint present may be the only part of the rock not affected by the acid.

The Kyle Prospect.

This property and the vicinity adjacent thereto represents the most northeasterly occurrence of sulphur in the district thus far exploited. An area here is bounded on three sides by the Maverick, Virginia, and Salt Draws, and is elevated enough above the beds of these draws to be locally termed a "dome", although it is likely that this so-called structure is merely due

to erosional effects and slumping, rather than to tectonic forces. The Kyle is at the north end of this elevation, and is located in the northeast corner of Section 18, Block 45. It is about fifteen miles from Orla, and about thirty-five miles from Toyah.

Around the Kyle, the surface is covered with alluvial gypsiferous soil or gypsite, with here and there a patch composed of fragments of the Rustler Formation, until about a mile west where the Rustler occurs in place. Red beds material in place, more or less mixed with the gypsiferous soil, occurs as bands from twenty to a hundred and twenty-five feet wide, following the drainage lines towards the draws, and seems to be wash material. Flint and quartz gravel is generally disseminated over the whole area, locally forming thin layers of conglomerate.

Red beds outcrop in the banks of the Maverick, Virginia, and Salt Draws, the thicknesses as exposed varying from 5 to 9 feet. They are composed of red sandstone and red clay, both containing white spots, disseminated throughout. These beds appear to be the uppermost part of the Castile gypsum. Their irregular nature is shown by the fact, communicated by Dr. Wm. B. Phillips, that a well drilled in the northeast corner of Section 1, Block 111, passed through forty-three and a half feet of white-spotted red sandstone, and after passing through 3 feet of massive white gypsum, under this, went 15 feet further in more red sandstone. The three feet of massive white gypsum passed through contained a little crystallized sulphur. At Maverick Springs in Maverick Draw, badland topography is exhibited within a limited area, the beds being composed here of fairly hard red clay, containing the characteristic white spotting.

On the east side of Virginia Draw, close to where it runs into Salt Draw, the section exposed from north to south shows the following beds: white Castile gypsum, dipping north; light gray massive limestone or dolomitic limestone, dipping east; gray gypsiferous sandstone, dipping south; and limestone or dolomitic limestone, dipping south. On the west side of the draw, there is an outcrop of white Castile gypsum, having a variable strike which is approximately N. 45° E., and a dip of about 20°, more or less, to the northwest. There is a little red beds material on top of this gypsum.

The dips and strikes noted above seem to indicate that they represent the flanks of a local dome. Considerable work has been done at the Kyle in the past, and at least two attempts were made to extract the sulphur from the rock. The remains of what was apparently a circular rock furnace, and a huge kettle with its accompanying steam boiler, are still to be seen. The work done here consists of an open cut, its greatest dimensions being about 200 feet in length by 100 feet in breadth, and 12 feet deep. There are also a number of scattered pits.

The main exposure of sulphur-bearing material is in the south-central part of the open cut, where a face about 8 feet high is exposed. This consists of siliceous, brown, porous, earthy, although quite compact, material, containing many pebbles, grading into a gray-brown conglomerate in the highest part of the face. The conglomerate is quite hard and consists of flint pebbles cemented by sulphur and siliceous material. Some of this is very rich. Small masses or boulders of gypsiferous material occur in the lower part of the exposure, no disseminated sulphur being noticed in these. Laterally, the brown earthy material, carrying sulphur, becomes in a short distance much lighter-colored; sulphur not showing in this part. Three kinds of sulphur were noted: a sulphur of a silvery or metallic lustre, filling minute fractures or seams in the brown earthy material; a massive yellow sulphur, sometimes the color of sphalerite, and resin-like when broken, filling small cavities both in the brown earthy material and in the conglomerate, as impregnations, sometimes appearing to cement the pebbles in the conglomerate, and as incrustations at times an inch or more thick; and a finely crystallized, lemon-yellow sulphur, crystallizing in any open space on the containing material or on the amorphous sulphur. This crystallized sulphur is quite generally distributed throughout the darker portions of a brown, porous, earthy material. The porous material, especially on being broken, gave off the odor of SO_2, very likely due to the oxidation of the sulphur by atmospheric oxygen.

Two of the shallow pits nearby showed a little weathered sulphur occurring in porous gypsiferous material or gypsite.

A pit put down by the West Texas Sulphur Company of Philadelphia, located about 200 yards northeast of the Kyle

open cut, showed some sulphur. The pit is 18 feet deep, and was sunk in decomposed gypsiferous material, gray brown to gray in color, and containing crystallized gypsum or selenite.

A white and blue chalky or talc-like material on the dump, apparently from near the bottom of the hole, contains a little greenish-yellow sulphur occurring in cracks with very finely crystallized selenite. Although this pit is located on an elevation there was some water standing in it.

It was reported that a good showing of sulphur was encountered at 26 feet in a nearby pit. Drillings near here are reported to have encounterd good showings of sulphur.

East of here on the west side of Maverick Springs, there is a salt seep that has been taken up as a sulphur claim. Incrustations of white to rusty brown colored salts are now being deposited. The odor of hydrogen sulphide is apparent, and the water blackens steel in a very short time. No sulphur was noticed, although it is possible that some may be deposited along with the salts mentioned above. The nearby banks are covered with crystals of selenite, probably deposited by the waters draining into the draw.

Open Cut on Section 14, Block 113.

Northwest of the Kyle property, about two miles, and on the north side of Salt Draw, there is an occurrence of sulphur in the form of bright yellow crystals associated with a small amount of selenite in massive gypsum. The quantity of sulphur appears to be very limited. Decomposed red beds material outcrops just north of here. A stream of water, running through this draw, has deposited a quantity of selenite crystals below a small waterfall.

The gypsum is cavernous and broken down on both sides of the draw but especially on the north side, where for long distances the gypsum is honey-combed on a large scale, some of the caverns being quite large and deep.

Prospecting on Section 13, Block 113.

Drilling for sulphur was being conducted here by some parties. It was reported that they also intended to drill on

Sections 14, 23, and 24, in the same block. Sulphur is reported as being on this section.

Block 112.

Samples have been examined of brown porous material containing considerable sulphur, reported to have come from near the Culberson-Reeves county line.

The Dot Prospect.

This property lies between the Kyle and the Michigan, and is in the southwest corner of Section 2 and the southeast corner of Section 3, Block 111. It is located about 17 miles from Orla, on the south side of Virginia Draw.

The formation here is quite similar to that around the Kyle, except that dolomite or dolomitic limestone and conglomerate are more abundant.

The Rustler formation is practically continuous up to a point southeast of here, and a heavy exposure was noticed about 1¼ miles east of here in the middle of Section 1, Block 111. This is a dense gray dolomitic limestone, pitted with very peculiar circular holes, very regular in outline, sometimes filled with soft white to light-gray calcareous material, perhaps standing out in the form of a button, and sometimes with calcite. The rusty-looking nodules of flint that are quite characteristic of the Rustler occur here. The beds dip west, just the opposite of the general dip of the main beds. This may be a natural dip with a syncline between this place and the Rustler Hills; it may be due to a fault, or to incipient faulting caused by the slumping of the gypsum beds beneath, or to the expansion caused by the hydration of anhydrite.

Several years ago some work was done at the Dot, and there are still to be seen several pits and cuts. One of the pits is 19 feet deep, and the material on the dump, apparently taken from the bottom of the pit, consists of badly decomposed gypsum, some of it iron-stained, containing some selenite and a little yellow sulphur. Nearby another small sulphur occurrence was

noted. Just southeast of the sulphur occurrences there outcrops in the gypsite a thin layer of dolomitic limestone, apparently dipping to the southeast.

Thin coatings of sulphur on gypsite or alluvial gypsum were noticed in two places in the Virginia Draw, just north of the Dot. Drillings near here are reported to have encountered good showings of sulphur.

Near here, in the same draw, there is what appears to be three sides of the remains of a dome composed of dolomitic limestone and some flint; dolomitic secondary conglomerate, with the thin layer noticed at the Dot, possibly representing the fourth side of the dome. The rock composing this dome consists largely of gray brown, much-pitted or cavernous limestone and dolomitic limestone, in places showing a network of apparently secondary material in the cavities. This appearance may have resulted from the partial dolomitization of the limestone or from the acid waters, as all of the drainage from the old Virginia runs this way; or probably from both these agencies. A similar material, less altered, shows what are apparently small cavities or cracks; due, perhaps, to the contraction incident to the dolomitization of the limestone. Some of the very cavernous rock is evidently secondary, as many quartz and flint pebbles are contained in it. Small green streaks are also noticeable. These appear to be due to algae as the coloring material floats off when the underlying calcium carbonate is dissolved out by dilute acid. Minute growing mossy bands were also noted, clearly of vegetable origin. These may have influenced the deposition of the calcium carbonate over them. A short distance to the west these beds become quite thin-bedded and flaggy and soon plunge under the overlying formation. In places the limestone is crossed by small, nearly parallel fissures filled with banded gypsum, their strike being about N. 30° W. The gypsum beds in the draw north of here are dipping to the northwest. On the east the sides of Virginia Draw consist of steep cliffs, especially on the north side, composed of cavernous broken down gypsum layers, and alluvial gypsum or gypsite. About one mile east of the Dot, red beds make their appearance on both sides of the Draw.

In the area under consideration there are many small caverns or sink holes in the gypsum, caused by solution.

The Spann-Felch Holdings.

The east half, eighty acres, of the old Virginia (Cedars of Virginia) property is owned by Dallas people. It adjoins the Michigan Sulphur and Oil Company's property and lies in the northeast part of Section 16, Block 111. There are no outcrops here, the surface being quite level and entirely covered with a mantle of gypsiferous soil. The property is a half mile long by a quarter of a mile wide, and prospecting has been done by means of pits, seven to thirty feet deep, which are fairly well spaced. Their distances from the west line vary from one hundred to seven hundred and thirty feet, and from the north line, from three hundred to sixteen hundred and forty feet. All measurements were furnished by Mr. F. W. Felch. There are fourteen of these pits, and sulphur is reported to have been found in all, except one which was not very deep. A fair sulphur showing was also struck at a depth of about 3½ feet in digging a camp cellar. Several of these pits were examined and may be described as follows:

Pit No. 6, 119½ feet from the west line and 521 feet from the north line, is 14 feet deep and shows brown friable gypsite containing small selenite crystals. Most of it is conglomeratic, containing flint pebbles and altered pebbles and boulders. Some disseminated sulphur occurs in a two-foot band near the bottom. It occurs in an altered, porous, conglomeratic material, containing much crystallized gypsum.

Pit No. 7, 210 feet from the west line, and 520 feet from the north line, is 10 feet deep. The first three feet from the top consist of gray brown gypsiferous earth and very porous gravelly gypsum. Below this is gray brown conglomeratic material containing flint pebbles and pebbles and boulders of limestone altered to soft gypsite, up to several inches in diameter. This conglomerate is similar to that seen in Pit No. 6, except that the conglomerate becomes dolomitic about two feet above the bottom of the pit. At the bottom there is a black material containing altered conglomerate in places, and this shows some

good sulphur. Sulphur also occurs in the gypsum just above, which is porous and altered, containing much crystallized gypsum.

Pit No. 14, 695 feet from the north line, is 7½ feet deep. The distance from the west line was not ascertained. Sulphur was struck at a depth of four feet and continued to the bottom. The top foot and a half consists of brown gypsiferous soil with white-gray patches, containing some pebbles. From here down, there was brown gray, altered gypsiferous material, conglomeratic with altered pebbles and flint, and containing considerable crystallized gypsum. The sulphur occurs as incrustations and crystals in cavities and crevices, and sometimes around the altered pebbles.

Pit No. 5, 100 feet from the west line, and 770 feet from the north line, is 30 feet deep. This pit showed the following from above downward: Top 8 feet, gypsiferous soil; from 8 to 13 feet below the surface, sulphur carrying rock, containing incrustations and crystals of greenish-yellow sulphur, the lower part of which is quite dark, probably due to the presence of organic matter, and also containing many altered pebbles and considerable crystallized gypsum; from 13 to 16 feet, conglomerate; 19 to 20 feet, conglomerate; 20 to 23 feet, earthy clay-like material; 25 to 30 feet, dark gray dolomitic conglomerate, containing pebbles varying in size from ¼ inch to 6 inches in diameter.

Pit No. 3, 355 feet from the west line, and 752 feet from the north line, is 30 feet deep. Work was stopped when the hard dolomitic conglomerate was encountered. An examination of the dump of this pit showed the sulphur as yellow crystals and incrustations, occurring in gray, altered, gypsiferous material, containing small flint pebbles; and in a very dark altered material, apparently largely reworked. According to Mr. F. W. Felch, there are several feet of each of these sulphur-bearing rocks.

A flow of natural gas was encountered near the bottom of this pit (hydrogen sulphide was found in several of the other pits), in sufficient quantity to explode and burn a man as he was lighting fuses for blasting. This gas issues from a small crevice, and is now walled off and conducted through an open

pipe to the surface. Sometimes the gas, when lighted, burns with a flame several feet high, while at other times air is drawn into the pipe fast enough to emit a faint whistling sound. In the table below are given certain observations on the flow of gas in this crevice. These were taken in the hope of securing some definite information on the relation of the gas pressure to barometric conditions in the atmosphere.

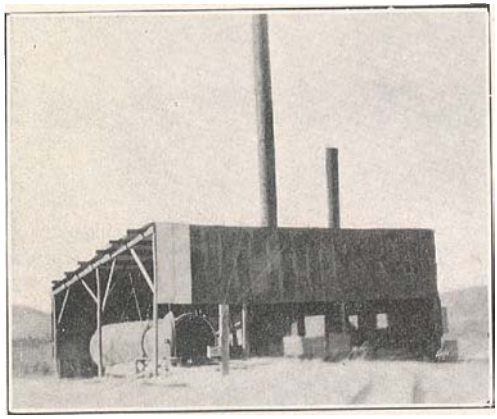
OBSERVATIONS ON FELCH'S GAS WELL, PIT NO. 3.

Date	Time	Barometer	Direction of wind	Flame
Nov. 28	7:10 p. m.	25.50	S. W. W. strong.	Violet blue with occasional tinges of red. About 1 ft. long.
28	9:10 p. m.	25.55	S. W. W. strong.	Extinguished.
29	9 00 a. m.	25.90	N. W. medium.	Sucks in with a whistling noise.
29	4:00 p. m.	25.90	N. mild.	Sucked in.
29	6.30 p. m.	25.90	Practically none.	Sucked in.
29	9:30 p m.	25 90	Practically none.	Sucked in.
30	7:00 a. m.	25 84	W. very slight	Sucked in.
30	12:00 m.	25.82	S. slight.	Not enough to burn steadily.
30	6:30 p. m	25.70	S. W. light.	Violet blue flame, with a reddish tinge about 2 ft. long.
30	11:00 p. m.	25.69	S. W. slight	Same.
Dec. 1	9 00 a. m	25 65	S W. W light.	Burned with colorless flame
1	2 30 p m	25 55	S W. medium.	Burned with colorless flame.
1	6:00 p. m.	25 54	S. W medium.	Same.
1	10:20 p m	25.55	S. W. slight	Burns with a violet blue flame.
2	6:30 p. m.	25.55	S. W , about 6 miles.	Gas burning, 1 ft. blue flame.
2	8:30 p. m	25.56	S. W , about 4 miles.	Gas out.
3	7:00 a. m.	25.53	S. W. light.	Gas burning, blue flame slight tinge of red, 6 inches.
3	7:15 a. m.	25.55	S. W. light	Gas draws down.
3	7:30 p m.	25.50	S. W. 4 miles.	Gas burning, 6 inch flame, blue, light tinge of red and yellow.
4	6:45 a. m	25 50	S. W. strong	Blue flame, 6 inches.
4	3:00 p. m.	25 51	S. W. medium	Burns with a small roar.
4	6:15 p. m.	25.50	S W. medium.	Wouldn't burn.
4	11:30 p. m.	25.51	W. medium	Wouldn't burn.
5	2 00 p. m	25.53	S. W.	Burned.
5	11:00 p. m	25.51	Light	Burned.
6	6:45 a. m.	25.43	Practically none.	Burned, strongly, blue and reddish flame.
7	6 30 a m.	25.12	S. W light	Burned, 1 ft. flame.
8	7:15 p. m	25.31	S. W. light.	Wouldn't burn
9	9 00 p m	25.39	S. W. light.	Burning, 2 ft. flame, blue, showing of red.
10	8 00 a. m	25.45	S. W., strong.	Wouldn't burn.
10	1:00 p m.	25 53	S W., high	Gas draws down
10	11:15 p m	25.69	W., very light	Gas draws down.
11	12:20 p m.	25.77	Almost W., medium	Wouldn't burn.
13	12 50 p. m.	25.14	N E. almost E., light.	Burns.
13	2 00 p. m.			Wind reversed its direction almost 180°, and the gas still burned.
13	11:00 p. m	25.40	Almost W., fairly strong.	Burning, blue, sometimes reddish.

From these data it seems to me quite evident that the flow of gas is directly dependent on variations in barometric pressure. The highest barometric pressure recorded was on Novem-

ber 29th and 30th, and during these days there was a flow of air into the pipe from which the gas escaped. Immediately when the barometer began to fall, on the 30th, the flow of gas set in again. On the 1st, 2nd and 3rd of December, the atmospheric pressure was constant and low, and during this time the gas continued to flow. On the 6th the atmospheric pressure was falling and on that date the flow of gas was strong. On the 8th the pressure was the lowest recorded during the time of the observations, and we would naturally expect a flow, but it must be remembered that the pressure had been low during the two preceding days and much gas had then escaped. The failure of the flow on the 8th may readily be accounted for as the result of exhaustion of the supply, for the gas had been quite steadily flowing for the last week. It will also be noted that there was only one observation made at 7:15 p. m. and the absence of the gas flow may have been due to a sudden increase of pressure due to a surge of short duration at the time of observation. At any rate, on the following day there was a strong flow during quite low atmospheric pressure. The gas was again drawn down from 1 p. m. to 11:15 p. m. on the 10th, when pressure was relatively high, and rising. The supply of gas is evidently small and the pressure conditions between the gas below and the atmospheric pressure above are no doubt nicely adjusted. The small variations that seem difficult to account for on the basis of changing barometer no doubt could be readily accounted for, if we had full information with regard to underground conditions affecting the richness of the gaseous contents of the ground, and regarding the depth of the source of supply. It is certainly safe to infer that the underground supply is constant, whatever variation there may be in the flow.

A hole was drilled 1416 feet north of the northeast corner of this property on one of several other claims controlled by this same company. The summarized log of this boring was furnished me by Mr. F. W. Felch, and is as follows:



a. Steam plant for extracting sulphur. Rustler Hills in the background. Michigan Sulphur and Oil Co.

b. Contact between dark, decomposed, cavernous, gypsiferous sulphur-bearing material and the overlying gypsite, a short distance above line drawn to show flexure. Michigan Sulphur and Oil Co.

SUMMARY OF LOG OF HOLE NO. 1, DALLAS CLAIM NO. 2

	Depth			
	From		To	
Gray gypsum	0		4′	6″
Brown gypsum	4′	6″	15	7
Gray gypsum	15	7	16	1
Fine gravel	16	1	18	9
Light yellow gypsum	18	9	19	7
Dark yellow gypsum	19	7	20	8
Light yellow gypsum	20	8	26	1
Gray hard gypsum	26	1	33	8
Yellow gypsum(?)	33	8	38	6
Hard strata, one foot to 39′	38	6	40	4
Soft brown gypsum	40	4	41	3
Brown gypsum(?)	41	3	44	6
Sandy gypsum, smell of gas	44	6	45	10
Gray sandstone	45	10	48	
Yellow sandy gypsum(?), showing sulphur	48		50	6
Light yellow gray gypsum(?)	50	6	51	4
Gray gypsum(?)	51	4	56	
Light yellow gypsum(?) containing sulphur	56		57	

The bailings were run into a shallow pit, and allowed to settle and harden. A piece was then broken out and examined.

The Holdings and Works of the Michigan Sulphur and Oil Company.

This company owns the west half of the old Virginia property, 80 acres located in the northeast part of Section 16, Block 111. The holdings lie just east of the main Rustler Hills, and are situated in an indentation formed by the foothills of the Rustler and the main hills mentioned above; a considerable part of the foothills to the southeast being present only as isolated remnants of the ridge. The property is drained by the Virginia Draw, which runs to the northeast, uniting with the Salt Draw between the Dot and the Kyle properties.

A considerable amount of development work has been done, and sulphur is exposed in many places. Most of the work has been done in and around a depression in the central and southern part of the north forty acres. Development has been by means of open cuts, pits and shafts. It is reported that drillings on this property have encountered sulphur at greater depths than have been reached by the shafts. With th exception of several shafts, one of which attained a depth of 43 feet, and many shallow pits, the work has been concentrated in two areas. An open cut has been made in the northern part of the sunken area and several open cuts and drifts have been exca-

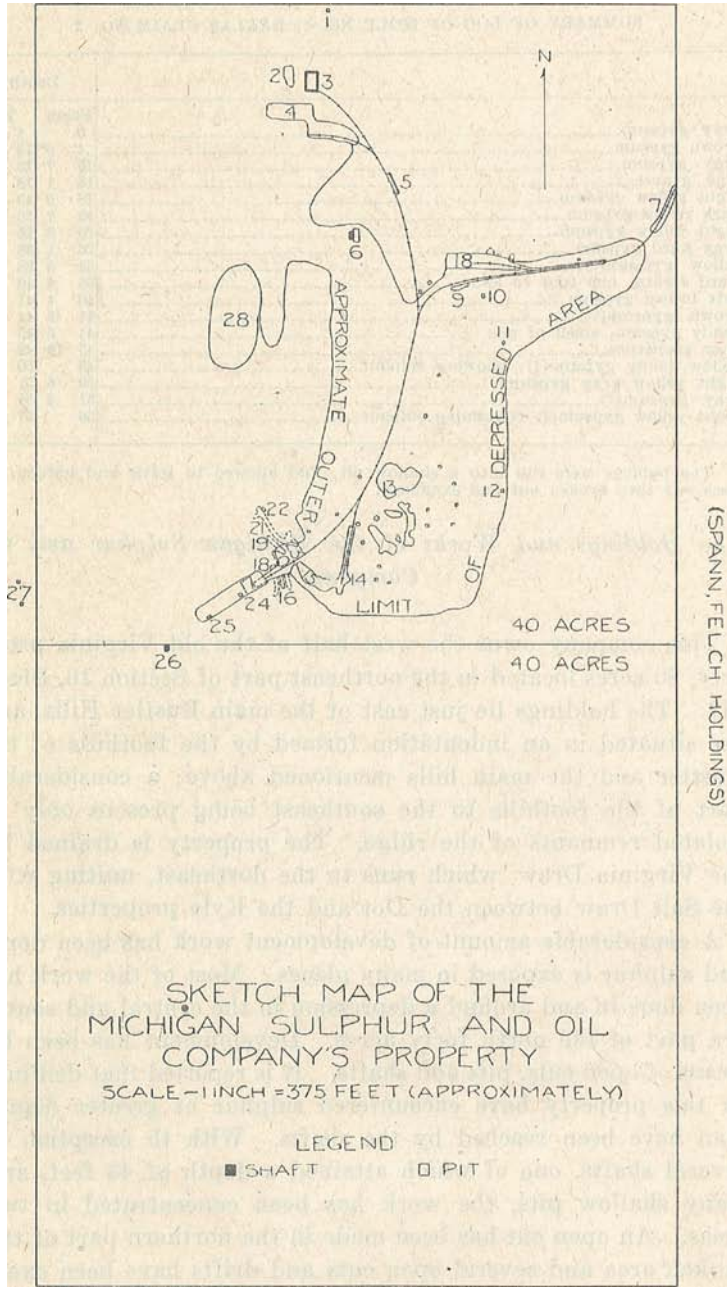


Figure 1.....Sketch map of the Michigan Sulphur and Oil Company's property.

vated in the southern and southwestern part of the same sunken area. This sunken area covers about 12 acres and drains to the northwest. Its surface is from 4 to 10 feet below the level of the surrounding country. It is covered with light gray gypsiferous soil containing many flint pebbles and it is barren of any plant life; whereas the surrounding area supports a scanty growth of yeso grass and a few junipers. Inflammable gas has been encountered in several of the workings.

The sulphur-bearing rock, as mined, is hauled to a loading platform, where it is loaded into special double-compartment, cast-iron cars having perforated sides and bottoms. Four of these cars at a time are run into the retort, which is then filled with steam at sixty pounds pressure. The retort consists of a horizontal iron cylinder, 30 feet long by 6 feet in diameter. One end of the cylinder is hinged, and the bottom slopes to a drain at the other end. The steam melts the sulphur from the rock and it drops through the perforations in the cars, flows down the inclined bottom to the drain, and out through the drain into a vat where it is allowed to harden. This steaming process takes some two and a half hours or more, depending upon the porosity of the sulphur-bearing rock. After a vat has become filled, the sulphur is broken into blocks. These have been stacked back of the retort house, and in December the pile was estimated to contain about two hundred and fifty tons of sulphur. Since then, forty tons of this has been shipped. It is reported that a second retort has been recently installed.

The accompanying sketch map shows the locations of the various cuts, pits and shafts.

Explanation of Numbers on Map.

(1) Pit about twenty-five feet deep, dump consists of gray gypsiferous earth containing no sulphur.
(2) Sulphur pile.
(3) Retort house, containing retort and two boilers.
(4) Dump for the steamed rock from the retort.
(5) Charging platform where cars are loaded before going into the retort.

(6) The deepest working on the property, and in fact, in the whole district; shaft about 18 by 12 feet, and 43 feet deep. From the bottom of the shaft shown in this sketch there are four drifts running approximately north 20 feet, east about 10 feet, south 50 feet, and to the west about 15 feet. The sulphur showing is continuous on various parts of the walls from top to bottom. The sulphur occurs as masses, incrustations, and disseminated crystals in the typical brown, porous, earthy material and altered black material. The black bands included in the brown material make many irregular bindings. The black material containing the most sulphur commences at about 20 feet below the surface. It is very cavernous and includes within itself small lenses of limestone or limy dolomite.

The black-banded condition extends to the end of the south drift, the sulphur content becoming less as the distance from the shaft increases. It extends also to the end of the north drift for a distance of at least twenty feet. The black-banded material pitches to the west under a mass of limestone or limy dolomite that appears just within the west drift. It continues also into the east drift. In places this black material is conglomeratic, and in other places is clay-like, some of it being quite white and plastic while moist; having an acid taste; but hardening after being exposed to the air for a few hours. The dump from this shaft contains much altered dark conglomeratic material.

(7) Dump for the steamed rock from the retort.

(8) Open cut, running east and west, and having a maximum depth of about 12 feet near the foot of a bench at the extreme western end of the cut, the bench being about six feet higher than the remainder of the cut.

Two drifts, working to the north, had just been started from the north side of the cut at the time of my visit, and the sulphur showing on both sides may be considered as commencing at the easternmost of these drifts, which was in only about 4 feet, and as continuing to the west end of the cut. Here the lower one and a half

feet consisted of a black and white mottled material, hard in places, in other places clay-like, cavernous, containing loose material in the seams, and also black secondary selenite. Sulphur occurs as incrustations in the cavities. The line of contact between this black material and the brown material occurring above is sharply marked, but is irregular. The brown layer persists upward for about four feet and then gradually merges into a gray gypsiferous earth, which persists to the surface. The brown material is conglomeratic, containing rounded pebbles of flint and black quartz. What was once pebbles and small boulders of dolomite or limestone is now altered, wholly or in part, to gypsite and gypsum. The physical characteristics of the brown layer are much the same as those of the darker layer below, for it contains inclusions of the dark material. The sulphur occurs in the same manner and much black gypsum is present; but it is not quite so cavernous.

The second drift, a few feet west of the one just described, shows similar conditions to exist, the main difference being that the line of demarcation between the black and brown layers is not so distinct, due to the fact that the brown material contains many more altered boulders and much more altered material, is more cavernous and fissured, and contains more sulphur than it did in the first drift. Incrustations of sulphur were noted occurring with clay-like material and in an altered pebble, probably once limestone. Between this drift and the bench, starting at the bottom of the cut, there is one foot of black material exposed. This contains considerable sulphur, both as disseminated crystals and as incrustations. The layer is somewhat conglomeratic, containing flint pebbles, and was apparently at one time much more conglomeratic, as the outlines of former limestone pebbles are still visible, now altered to a gray or black gypsiferous material. This layer can be traced around the face of the bench into the opposite south side at the bottom of the cut, where it is overlain by brown, porous, yet quite

hard, earthy and somewhat conglomeratic material, containing small quartz and flint pebbles, and, especially near the bottom of the cut, patches and small layers of very dark conglomerate, most of which is altered. Some of the pebbles have sulphur deposited within them. Both the dark altered conglomerate and the brown earthy material contain considerable sulphur, both crystalline and massive, generally disseminated throughout. Some of the crystalline sulphur is greenish-yellow. On the north side of the cut the line of contact between the layer of dark altered conglomerate and the layer of dolomitic conglomerate above it, which is absent on the south side of the cut just described, is quite irregular, and the sulphur content seems to increase near this contact.

This conglomerate varies in thickness from two to four feet, and consists of fairly well-rounded pebbles and boulders of brown, dark gray, and almost black dolomite, sometimes iron-stained, varying from one-eighth inch to five inches in diameter. The cementing material is very frequently calcareous. The conglomerate becomes thinner as the bench at the west end of the open cut is approached and contains very little sulphur. Above this there are two or three feet of black decomposed material, now more or less weathered and generally soft. The contact between this layer and the dolomitic conglomerate below is fairly well marked, but is very irregular. It is very cavernous, and contains considerable sulphur in leached out parts and cavities. The line of demarcation between this layer, which lies about five feet below the surface, and the top, light brown, gypsiferous soil is also fairly well marked, but irregular. Portions of the black material extend up several inches into the soil. The exposed face of the overlying soil shows here and there a thin incrustation of badly weathered sulphur, in places extending up to the surface. It also contains some sulphur near the contact with the black material. It is difficult to say just what is the chief cause or causes of the well defined yet wavy or irregular

contacts so characteristically shown in these excavations. They are evidently not due to folding. They are probably due to several causes combined. They may represent the upper limit of the strongest action of ascending waters, or the lower limit of surface leaching. The darker, more altered part of the ground may have had a higher lime or dolomite content, and may have been, therefore, more subjected to alteration by gases and water solutions. Much lime is present over all of this district, not only in limestones and dolomites, but also in altered pebbles. This is true also of the cementing material in certain dolomite conglomerates and also of some calcareous tufa. The dolomite pebbles and boulders appear to have resisted alteration by hydrogen sulphide and sulphuric acid much more than those composed of limestone. Some parts of the conglomerate contain sulphur. In the parts where dolomite is the most persistent material, the sulphur content is smallest, in some cases not appearing at all. Yet in others, apparently (to the eye) just as closely cemented, the pebbles of the conglomerate have been considerably altered to dark gypsiferous material, and much sulphur may be present, generally between the pebbles and in joints. Sometimes in the outer edges of the pebbles themselves where much leaching has taken place, and even where sulphur is present in or around dolomitic parts, it displays a selective relation towards materials that have lent themselves more readily to some alteration. The dark organic material present may be the organic detritus from the altered limestone. On the north side above the bench, the line of contact between the brown soil and the dark layer lying beneath it is not so well marked as some of the other contacts, the brown and black materials grading up and down slightly. This condition continues until the end of the bench is reached. The dark layer in this distance is slightly rolling, rises about two feet, is cavernous and in some places has quite a rich sulphur content.

There is a seven-foot pit at the western end of the

bench and the conglomerate below the upper dark layer shows up for about two feet in the side of this pit. Here the dolomitic part was either altered, or has changed its character, for it contains altered pebbles and boulders. In fact, it seems to be identical in some respects to the dark altered conglomerate underlying the dolomite conglomerate at the foot of the bench. The conglomerate in the pit also carries considerable sulphur. Opposite this pit, on the south side, this same conglomerate approaches closer to the surface, and near its top is more or less mixed with the brown earthy material. This mixed material contains considerable sulphur in places, and also some very hard boulders or nuclei, which on being broken show much sulphur and metallic sulphides, probably pyrite.

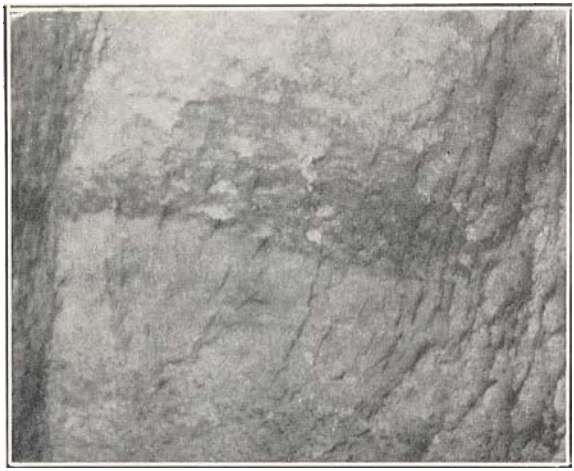
(9) Shallow open cut. The lower three feet consist of brown earthy, hard conglomerate containing some disseminated sulphur. The upper three feet consist of lighter brown gypsiferous earth and appear to contain no sulphur.

(10) and (11). Seven-foot pits, exposing gray-brown, gypsiferous, conglomeratic earth from the surface down to near the bottom, where there commences a black-gray, altered conglomerate carrying some sulphur, both crystallized and kaolin-like, and selenite.

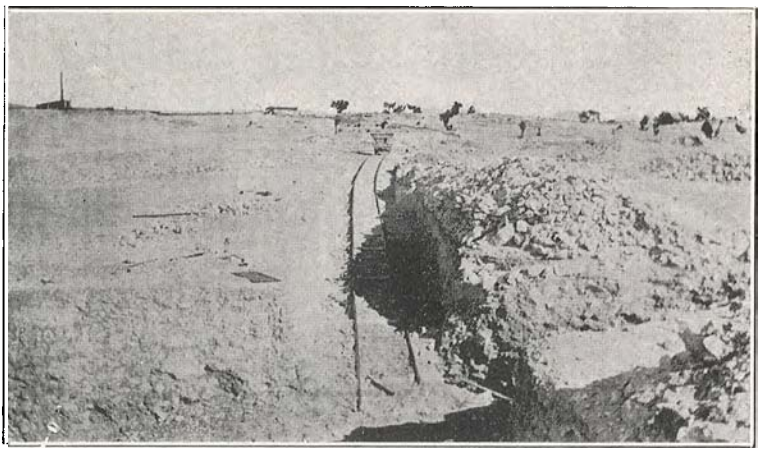
(12) Seven-foot pit. Dumps show gray white, gypsiferous material, and some much altered conglomerate. It is badly weathered and was probably much darker when fresh. A little sulphur was noticed in the conglomeratic material.

(13) Here occurs by far the best sulphur exposure to be seen in this cut or in the three large irregular cuts immediately south of here, and this may be taken as a type for the rest. The one exception noted was the occurrence in one of the other three cuts referred to, of some sulphur in a more friable, white gray, decomposed gypsiferous earth.

Starting at the bottom of the cut there is from one to two feet of very rich sulphur-bearing material exposed, similar to the deposits occurring at 16. There is also



a. Entrance to the northeast drift at 16 in sketch map. Showing contact between the dark, gypsiferous material, and the brown, earthy material above. There is a great deal of kaolin-like sulphur in the dark material. A picked sample from the opposite side of this drift contained 5.4 per cent of free sulphur Michigan Sulphur and Oil Co.



b. Part of the workings of the Michigan Sulphur and Oil Co. Looking north from the center of the south line of the north forty acres, near the south edge of the depressed area. Extraction plant in the left background. Photograph furnished by Mr. J. G. Townes.

disseminated crystallized sulphur, both in hard brown, gray, and black material, which is conglomeratic as at 8. The brown and black material is more mixed than usual, black masses occurring in the brown material. In fact, this deposit displays the characteristics of both 8 and 16. Some sulphur of a silvery lustre was also noticed from near here.

There are a number of pits, varying in depth from three to ten feet, scattered around these four cuts. Most of the deeper ones show a little sulphur in their dumps, which are badly weathered.

(14) Gray brown, gypsiferous earth, and a darker brown material are seen at this point. Three feet of the bottom ground contains considerable sulphur, disseminated and in seams, some of the seams being three-fourths of an inch thick.

(15) On the north side of this open cut, the upper five feet of the section exposed consist of brown, black-spotted, compact, earthy, gypsiferous material containing some sulphur quite generally disseminated, but sometimes more concentrated in places, and there are many crystals of selenite. The lower three feet consist of a mixed dark brown and black, gypsiferous material, apparently containing more sulphur than the brown material above, the general occurrence being much the same in both places.

The brown material is conglomeratic in places, containing pebbles of flint and quartz, and altered pebbles, which were probably once limestone. On the south side of this cut there is exposed much the same general condition of the brown and black material, although it is more altered than the material above. It contains many acicular crystals of selenite, and sulphur as disseminated crystals, in small masses, and some fibrous banded layers up to an inch and a half in thickness. The fibrous seams of the sulphur are at right angles to the general direction of the crevices or solution channels. These appear to pitch toward the south at about a sixty degree angle. This general condition persists on both sides of the cut west to the track, except that on the south side the black

material comes closer to the surface, about four feet of it being exposed. Here it has a banded and rolling appearance, and is cavernous.

(16) There are three drifts here under about an 8-foot capping. At the entrance of the one nearest to 15 there is exposed a 4-foot layer of the black material with a well marked, although irregular, contact with the hard, brown, porous material above. At the back of the drift this thickness decreases to about two feet. Considerable selenite is scattered throughout the ground. Much of the sulphur in the lower part of the black material is like kaolin in texture. It is present in well-defined, irregular or wavy, bands or layers. In places, some of these bands have a fracture at right angles to their longitudinal extent. Some bands are two or more inches in thickness. In the upper part of the black material, and in the lower two or three feet of the brown material, there are many cavities or open spaces, and many of these are lined with beautifully crystallized sulphur. Some of the crystallized sulphur is greenish-yellow. The upper part of the dark material is lighter than the lower part, and the sulphur in the brown material seems to show a preference for the browner, more altered, and more porous parts. The conditions outlined above hold true for the other two drifts. A white efflorescence of salt was noted on the brown and to a lesser extent on the black material at the back of the drift. This is most likely caused by surface seepage and evaporation.

(17) The physical conditions exposed here are much the same as those described under 16, except that the sulphur showing, which is quite rich there, gradually diminishes in this direction until very little is present here.

(18) A three-foot exposure of the black material is exposed here, the sulphur showing up well again. Otherwise, the ground is similar to that at 16 and 17. This continues around wherever the cut is exposed all the way to 19 and 20. The drift at 21 is on the contact between the black and brown material, which is almost directly over-

head practically up to 22, where the black condition either stops or swings out of the drift.

The brown material here displays the usual characteristics, but it has here much disseminated sulphur, and considerable banded sulphur, especially near the contact, where it is quite rich. Some distance before 22 is reached, sheets of the most beautifully crystallized emerald green sulphur start in and persist to 22.

(23) The brown material, with apparently a decreasing sulphur content, persists to here.

(24) Shallow pit. The dump shows a little sulphur in a dark, altered, gypsiferous deposit, containing selenite.

(25) Like 24.

(26) Shaft about 30 feet deep, containing several feet of water. Material on the dump shows sulphur occurring as layers, incrustations and seam fillings in white or gray friable material, and in the cavernous darker rock. The darker parts contain the greater part of the sulphur. Some of the cavities in the darker portions contain a thin lining that looks like wad.

(27) Two 10-foot pits, in white or gray friable, gypsiferous earth, containing a very little sulphur, apparently from near the surface.

(28) A low knoll or elevation, covered with fragments of Rustler dolomite.

The Georgetown Prospect.

This deposit is located on a hill in Section 10, Block 42, some two and a half miles southwest of Rustler Springs, and about one-half mile west of the main body of the Rustler Hills. Rustler dolomite or dolomitic limestone evidently once entirely covered this hill, as broken pieces are at present scattered all around. There are many small hills in this vicinity, at varying distances from the main Rustler Hills. Practically all of these hills exhibit the rounded appearance due to the presence of the limestone or dolomite. Evidently this has once been present and has been recently removed by erosion. Some of the gypsum in the hill may have originally been limestone, later altered by

sulphuric acid. The odor of hydrogen sulphide is quite perceptible.

The showing here is good, and six shallow pits and cuts contain sulphur, some of it quite rich. The pits are somewhat scattered, some of them being as much as 150 feet apart. The occurrence of sulphur here is quite typical, occurring in white to gray decomposed gypsum, which has the usual leached appearance. There is one showing near the top of the hill, the sulphur lying just under a ledge of harder material. The ledge in this case may have acted as a capping against which the sulphur was retained. A test of a recent Julus, incrusted with sulphur, was picked up in this immediate vicinity.

The Cooksey Prospect.

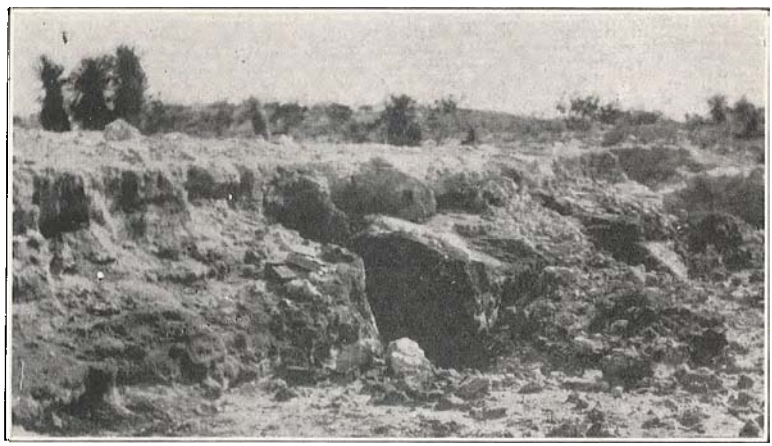
This property is west of the Rustler Hills and is located in Sections 10 and 15, Block 114. By automobile road to the Michigan it is distant from that property about 7 miles; and from Orla, about 25 miles.

Hills capped with the Rustler formation extend to within a short distance of this place, and small hills covered with remnants of this rock extend some distance beyond. This, taken in connection with the abundance of dolomitic limestone or dolomitic pebbles present in the local conglomerates, shows that the Rustler dolomite or dolomitic limestone once covered this area, and has been removed by erosion.

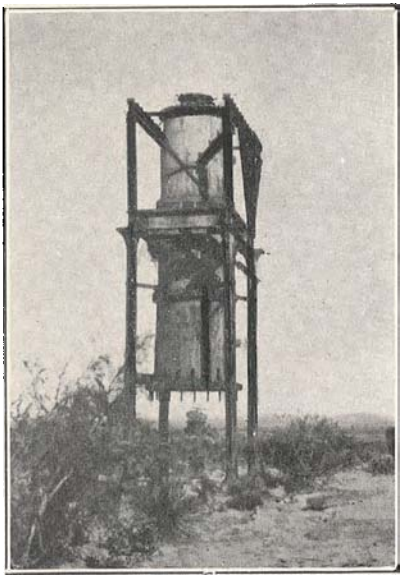
This vicinity shows the same monotony of exposures as the area just east of the Rustler Hills, except that red bed materials are lacking. The surface around here is covered with alluvial gypsum or gypsite, with more or less frequent exposures of massive Castile gypsum and the patches of fragmental Rustler mentioned above. Flint pebbles are abundant and widespread. Gypsiferous conglomerates are quite abundant, the pebbles consisting chiefly of flint and dolomite or dolomitic limestone. A little sandstone is present at times.

Considerable work has been done here and an old retort is still standing, minus the lower part used for extracting the sulphur from the rock with super-heated steam. It is said that about 75 tons of very pure sulphur were produced. Most of

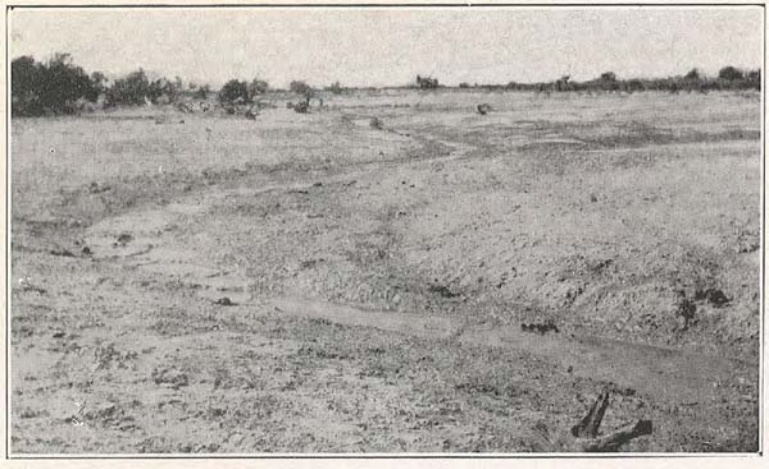
a. Rustler Hills, looking south from about the center of the Michigan Sulphur and Oil Company's property. Gypsite covering in the foreground.



b. Best showing of sulphur on the Cooksey Prospect. Brown earthy siliceous material overlain by a thin capping of gypsite. A picked sample from here contained 41.8 per cent of free sulphur.



a. Furnace on the Cooksey Prospect Said to have produced 75 tons of sulphur; built about 1900. The foundation of the furnace rests on Castile gypsum. Rustler Hills in the distance.



b. Stinking Seep. Looking to the northwest. A rusty brown incrustation now being deposited here on the gypsite contained 3.2 per cent of free sulphur. Typical Castile gypsum outcrops in the vicinity.

the work was done in an open cut, quite irregular in outlines, and running almost north and south; its greatest dimensions being approximately 200 feet in length, 80 feet in width, and 6 feet in depth. In this open cut there are several pits, cuts, and trenches. The best exposure of sulphur-bearing rock is in the extreme northeastern part of the workings and consists of a bank about 25 feet long and 5 or 6 feet high. The sulphur begins to show beneath about three feet of gypsiferous earth. It is brown, porous and earthy, but quite hard, highly siliceous material. In some places it shows a conglomeratic nature, flint pebbles predominating. The sulphur carrying rock has a maximum thickness of about 5 feet; the mineralization is not uniform, however, the upper two feet appearing to be the richest.

Sulphur is present as a variety having a silvery or metallic lustre, filling small cracks and fissures. It is in part banded. Yellow sulphur, exhibiting all shades from lemon to greenish yellow, is generally crystalline here, but also massive. It occurs along seams or in somewhat porous places, and very frequently crystallizes on the silvery sulphur, showing that it is a later deposit. A nearby pit exhibited a gray gypsiferous and sandy conglomerate, containing pebbles of flint up to ¼ inch in diameter, and crystals of selenite. Towards the center of the open cut there are several pits. The greatest depth reached by these pits beneath the original surface is not much more than twelve feet. The section exposed by these pits consists chiefly of brown earthy material, quite hard in places, except in the lowest parts, where there is some irregularly black-banded, partly crystallized gypsiferous material, and conglomerate. Flint pebbles are plentiful in the conglomerate and it contains considerable sand. Some crystallized yellow and greenish yellow sulphur was present in the black-banded material.

About 200 feet southeast of here there is an exposure of what is apparently a vein of secondary gypsum, containing a little crystallized sulphur in crevices.

The Stinking Seep Prospect.

Stinking Seep, sometimes called Chemical Springs, is probably located on Section 44, Block 60, about 3 miles northwest

of the Cooksey. It is a small spring highly charged with salts and hydrogen sulphide, and probably some sulphuric acid. Although the quantity of water that flows here to the southeast is not large, yet a considerable area is influenced by it, judging from the lack of vegetation in the immediate vicinity of the springs.

Considerable fine sand was noticed just east of the spring. An outcrop of white massive Castile gypsum occurs at the east end of the spring, the waters passing over it. Yellow incrustations occur in abundance over the whole area that has been worked over by the spring waters. Just north of the spring heavy beds of massive Castile gypsum outcrop in the form of low hills, capped with white to brown granular limestone, probably of secondary origin. Four shallow pits in this vicinity show a little sulphur. The sulphur occurs as crystals and incrustations in friable decomposed gypsum, in small white areas that have apparently been leached by water.

Deposits Near Walker's Ranch.

A six-foot pit located in the southeast corner of Section 4, Block 109, shows decomposed white grayish gypsum, at the surface, then typical brown, earthy, siliceous material to the bottom. Some small vertical seams of sulphur were noticed in the sides of the pit.

In the southern part of Section 4, Block 109, there is a six-foot pit situated in the midst of a large white, leached area, some hundred feet in diameter. This pit exposes in the order named typical gypsite at the surface, white to gray decomposed gypsum, then brown earthy material in one side, and more or less of the fine-banded gypsum. The banded gypsum contains in places fragments of thin-bedded, brown, bituminous limestone, smaller fragments of which are also scattered throughout the decomposed gypsum. A little sulphur was noticed in one corner of the pit. Considerable yellow sulphur, both crystallized and massive, is present throughout the small dump, from this pit, some fragments being quite rich. This is also the only place noted where sulphur occurs as a coating on the bituminous limestone. The limestone does not exhibit any

marked alternation and probably effected no selective action on the sulphur emanations, other than that it was the most convenient area for deposition.

There is a five foot pit about 150 feet northeast of the pit described above. The section exposed here is similar to the section exposed there, except that the thin-bedded bituminous limestone is lacking. Sulphur occurs in the banding in the badly decomposed white gypsiferous earth and in a brown earthy material. Besides the yellow sulphur, both crystalline and massive, a little silver sulphur was also noticed.

A fine showing of sulphur was noted in a three foot pit, which is probably in the southwest corner of Section 4, Block 109. The sulphur at this place occurs in gray brown gypsum, some of it apparently once banded, and also in brown, compact, earthy material. Massive banded sulphur, crystalline yellow sulphur, and massive silver sulphur are all present. There is more of the silver sulphur here than at any other place noticed. A somewhat concentric structure is developed in places in the banded yellow sulphur. A two foot assessment pit located fifteen feet northeast of here, shows the effects of water action, but no sulphur. Fifteen feet west of the three foot pit, good sulphur is present just below the surface.

On the southwest quarter of Section 9, Block 109, there is a good showing of sulphur on the south side, where some stripping has been done, and also on the top of one of the low gypsum hills, capped with limestone. These are characteristic of the western belt covered by the Castile gypsum. The limestone is quite similar to the capping at the Grant, a brown minutely banded, somewhat bituminous limestone, with layers, sometimes several inches thick, of hard, massive, dark brown and highly bituminous limestone.

The hill is badly broken down, and small blocks of the laminated rock are tilted at all angles to their original position. Both the yellow and silvery varieties of sulphur were noticed. The yellow sulphur occurs as incrustations or fillings, both crystalline and massive. A very little silvery sulphur occurs in small seams. In this hill the occurrence of the sulphur is invariably associated with white, decomposed patches of gypsiferous material appearing on the surface of the ground, which

look as if they might be leached by seepage. These patches vary from 20 to 50 feet in diameter, although they are not always circular in outline. The original banded layers can be traced grading into the white-gray, decomposed material. In some places harder layers have resisted erosion and form very small cliffs, from beneath which the water seems to have come, the hard layers perhaps preventing it from rising to the surface.

In the northeast corner of Section 10, Block 109, there is a seven foot pit showing a foot of white gray gypsite at the surface, and below this brown earthy material to the bottom. The lower two feet contain yellow sulphur, and yellowish green crystallized sulphur occurs in seams and open places. There are also streaks of silvery sulphur.

The dump consists of white gray gypsite containing selenite and considerable weathered yellow sulphur is present, some of it being more than an inch in thickness. This sulphur on the dump probably came from the very top of the pit. Gas was noticeable at all of the sulphur exposures in this vicinity, both H_2S and SO_2.

At all of these exposures there was a bare leached area around the sulphur, with the ground white to gray in color and slightly sunken, apparently due to the action of circulating or stagnant water. These shallow depressions are more or less circular or oval, from 20 to 100 feet in diameter, and are characterized by a lack of vegetation. Some of these depressions were noticed where there was, apparently, no sulphur at the surface.

Prospects On and Near the University Lands.

In the northeast part of Section 1, Block 46, and in Section 7, Block 115, there are sulphur occurrences located on the west side of a hill whose longer axis runs approximately from north to south. The hill is largely composed of fine-banded gypsum, covered in many places with white to gray gypsiferous earth. Selenite is abundant in the gypsum. One mass of selenite was several feet across. This was seen on the western edge of the hill. Several ravines have cut their trenches into the hill, their courses varying from northwest to southwest. The capping of

the hill consists of an altered limestone, quite cavernous and the crevices containing much stalactitic material.

The sulphur occurs around the western edge of the hill in white, more or less circular or oval, areas, sometimes seen to be depressed below the general surface of the land. These have perhaps been formed by the action of moving acid waters, either descending or ascending, which have decomposed and worked over the gypsum and limestone, in the immediate vicinity. The worked-over areas in this vicinity are small, generally not over 30 feet in diameter.

The sulphur occurs as thin incrustations in the banding of thin-bedded gypsum, and in cracks in the same rock. It is also present as a closely granular form in white or gray gypsiferous earth, which contains in places much selenite. In places, sulphur is present as massive incrustations on broken or exposed bedding planes and other surfaces. Straight bands of sulphur, slightly elevated above the surface of the more massive incrustations in some places tend to enclose diamond shaped cavities. These may have been formed by the solution of the gypsum, which was partly inclosed by the cracks filled with sulphur. Five claims have been filed on this land, covering all of the known sulphur exposures. There are five shallow cuts, two pits, and one pit and cut combined.

No sulphur was noticed in any of the pits below the upper two feet. Hydrogen sulphide was perceptible at all of the openings. Two of the pits contain standing water. On the edge of the pit in the combined pit and cut, in the inside wall of which a gypsum vein is discernible, there is a timber, probably placed in position during the progress of the work. This has been so completely attacked by acid fumes, that it is completely charred.

The Grant Mines Property and Vicinity.

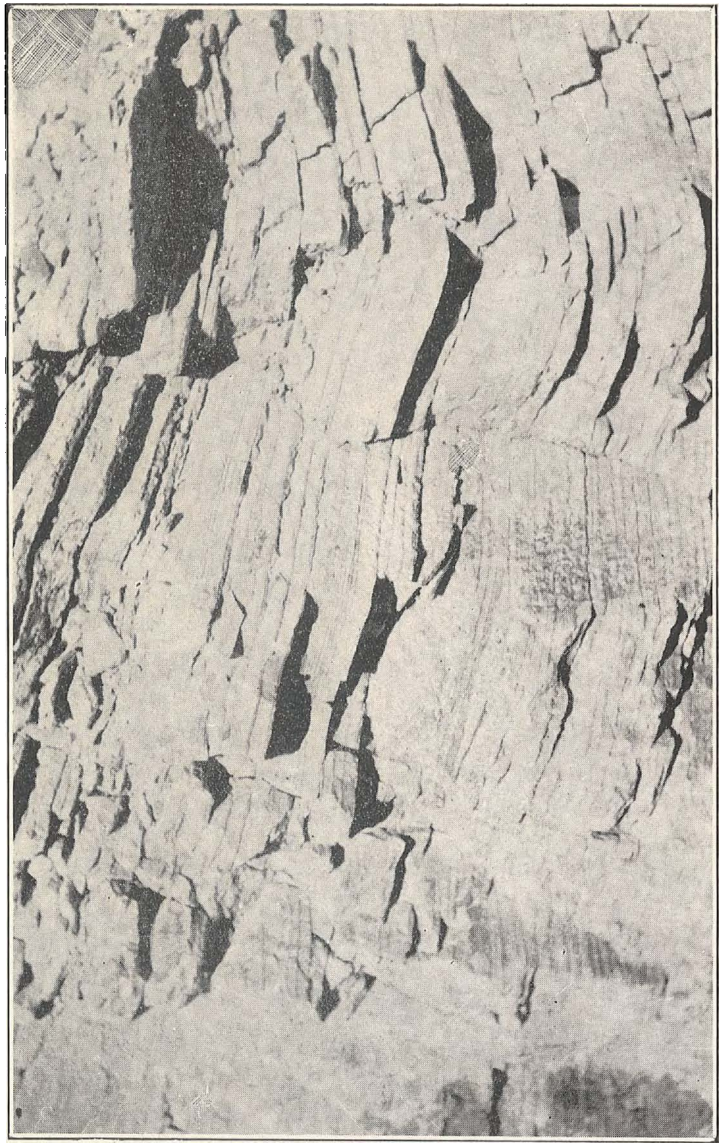
There are three hills, all possibly the remains of a former hill, on the eastern section line of Section 18, Block 61, Township 2. These hills are interesting, not alone from the fact that there is a sulphur occurrence here, but also because of the structural relations shown. The three hills may be more properly re-

garded as two, and may be conveniently referred to as the east hill and the west hill, the west hill having two peaks with a saddle between them.

The lower part of the west hill is composed of thinly banded gray gypsum, the bands being from one-fifteenth of an inch to a half inch in thickness. Between the bands there is a thin layer or parting composed of dark brown bituminous calcareous material. These thin bands are complexly folded. The minute folds are sometimes not more than a quarter-inch from crest to crest. At times they flatten and give out both vertically and horizontally, and then commence again. An incline in the east side of this hill exposes about 40 feet of this gypsum, and it is quite uniform throughout. The only variation noticed was a variety having a little sulphur associated with selenite occurring as incrustations in minute fissures and along the banding. The main beds exposed are also folded, the folds being several feet wide from crest to crest. Both the minute and the more extensive folding may be due to the swelling accompanying the hydration of anhydrite, and its recrystallization into gypsum; or the finer folding may have been ripple marks originally, which have been later intensified and distorted by either the swelling incident to recrystallization or by pressure due to slumping. The larger folding may also have been caused by slumping. The very thin partings of bituminous limestone probably represent the deposition at times when the salinity of the water was diminished by overflows. Pl. 7.

The upper part and capping of this hill is composed of a weathered, cavernous, somewhat bituminous limestone, very minutely banded; the bands are much distorted and broken. About half way up this hill there is a thin layer, apparently less than two feet thick, of hard, thinly-bedded limestone. It is finely crystalline, dark brown, highly bituminous, and the layers average a half inch in thickness. It seems to be very little altered and is present on the sides of the east hill. Fragments of this limestone were traced from here south about a quarter of a mile, showing that it was formerly much more widely distributed.

The external characteristics of the east hill are much the same as those of the west hill, but here the resemblance ends. The



Banded gypsum at the entrance of the incline on the east side of the west hill. Grant Mines Property.

work that has been done on both the east and west sides of this hill tends to show that the hill has a limestone core and that solutions have been active in and around the outer layer of this core. An open cut starting at the west base of this hill and extending eastward, passes through the solid finely-banded gypsum, and into about five feet of gray brown, cavernous, crystallized gypsum. The contact between these two is vertical and is clearly defined. Next to the brown and cavernous crystalline gypsum, eastward, are about four feet of very fine, friable, white, siliceous material, containing some gypsum. Then there is about 15 feet of white, brown, and black-banded gypsum, and limestone containing patches of selenite. This gypsum is evidently altered limestone, for in places the two merge and it is impossible to see where the limestone stops and the gypsum begins. This grades into more solid black gray limestone, cavernous and decomposed in places. Small fillings and incrustations of sulphur were noted in places, and some sulphur dust (small fragments) was taken from a small cavity in the working face.

In thin section this limestone is seen to be composed of interlocking grains of calcite. It has the appearance of being considerably altered. It also contains bituminous material. From the top of this open cut, the rock has been stripped toward the summit for some distance. The limestone exposed here is very finely banded, minutely folded; it is gray brown from the bitumen it contains. Many minute cracks and fissures, especially along the bedding planes, were noted, quite a few of them being wholly or in part filled with secondary gypsum. A little sulphur was also frequently seen to be deposited on the secondary gypsum. These fissures and small caverns were possibly caused by the same solutions that were active in forming the altered material in the open cut below, for they become less pronounced as the distance from the outer edge increases. About two-thirds of the way up the hill and a short distance north of the open cut, there is an exposure of sulphur occurring in decomposed friable, brown gray or white, gypsiferous material. At this point considerable hydrogen sulphide is given off at times.

At about the same elevation and just south of the line of the open cut, there is a natural shaft-like opening, said to be 100

feet deep and to have been lined in places with sulphur, which has been removed during some work done several years ago. An incrustation of sulphur was noticed on the wall just above the mouth of the shaft. There was also a vertical gypsum vein, about four inches thick, in the south wall. It consists of decomposed earthy material. Sometimes the hydrogen sulphide issuing from this shaft is perceptible at a distance of fifty feet or more.

On the east side of this hill and about two-thirds up its side, stripping has uncovered a good showing of sulphur-bearing rock, for a distance of about 40 feet. This deposit, where exposed, has a thickness of about four feet, and certain parts of it are very rich. Directly in contact with the sulphur, the containing rock is white and altered, but a short distance away, where it has evidently not been altered, by the hydrogen sulphide, the limestone is practically identical with that occurring in the open cut on the west side.

A few feet below this sulphur exposure an open cut has gone in far enough to show that the limestone is very similar to that in the other open cut. But the mineralizing action has been less intense around the outer edge. A lump of sulphur was noticed from this cut, and in places the cavities in the rock were lined with petroliferous material.

Open Cut on Section 8, Block 61.

The thin-banded condition of the gypsum persists northwesterly from the Grant, and a little white massive gypsum appears here and there on the surface. This becomes more calcareous as the base of the gypsum is approached.

There are several hills northeast of the Grant that have a similar capping of weathered limestone. In fact, between the north and south limits covered, this capping seems to be quite typical for the western edge of the gypsum.

About one mile north of the Grant, and probably on the extreme western edge of Section 8, is a shallow pit, showing some yellow sulphur in loose, decomposed, white to gray gypsite or gypsiferous earth. The odor of hydrogen sulphide is readily perceptible at this locality.

Other Sulphur Locations Reported.

A number of other reported locations of sulphur were obtained from authentic sources. These are on Sections 9, 10, 11, 13 and 14, Block 111; Sections 5 and 24, Block 109; Sections 10, 11, 18, 19, 22, and 23, in Block 115; Sections 15 and 16, Block 60, Tsp. 2; Sections 16 and 17, Block 61, Tsp. 2; Sections 48, Block 62, Tsp. 1.

TYPES OF SULPHUR.

From the descriptions of the local deposits of sulphur occurring in this field, it will be seen that some distinctions can be made of different forms the sulphur deposits have assumed. We may group these into a few general types, which cannot, however, be said to be distinguishable in every case, but which merge very frequently into each other. A study of these types and their relation to the different kinds of matrix, or containing rock, is quite instructive and suggestive of the conditions under which mineralization has taken place. The most readily distinguishable types are as follows:

1...Yellow crystallized sulphur is very common; especially when it occurs in association with brown, porous, siliceous material, in which it is usually well disseminated. The common size of the crystals is from a pin point up to about one-eighth inch in diameter. Some of the crystals in the massive gypsum may become much larger than this size. The color varies from resin-yellow to greenish-yellow.

Occurrences of this type of sulphur were noted in the following locations: On Section 34, Block 70; Johnson; Kyle; Section 14, Block 113: Section 1, Block 111; Spann-Felch; Michigan; Georgetown; Cooksey; Stinking Seep; Section 4, Block 109; Section 9, Block 109; Grant.

2...Yellow massive sulphur is the most common variety of sulphur, forming the bulk of the deposits. It occurs in seams, layers and masses, ranging in thickness from that of a knife blade edge up to a foot or more. It sometimes exhibits banded or concentric layered structures, as if the layers had been deposited around a common center. The color varies from drab yellow and greenish yellow to very light yellow.

Occurrences were noted at the Johnson; Kyle; Dot; Spann-Felch; Michigan; Georgetown; Cooksey; Stinking Seep; Section 4, Block 109; Section 9, Block 109; Section 10, Block 109; Grant; Section 8, Block 61; University Lands.

3...Green crystallized sulphur occurs rather sparingly, the

Michigan being the only property where it was noted as occurring in any abundance. The size of the crystals noted ranged from almost microscopic size to about one-quarter of an inch in diameter. The color ranges from emerald green to yellowish green.

This variety of sulphur has probably been deposited both from gases and gases in solution in water. The green color is probably due to contained impurities, although it is possible that physical properties also affect the optical qualities of the sulphur.

Occurrences of this type of sulphur were noted at the Spann-Felch; Michigan; Cooksey; and Section 10, Block 109.

4...There is also a green massive variety of sulphur. Occurrences of this type are very rare, and form no appreciable portion of the deposits I have found. It occurs in thin layers, and is of a yellowish green color. This was noted at the Cooksey; Kyle; and Spann-Felch properties.

5...One variety of sulphur is silvery white and massive. This occurs frequently, but in small quantities. It occurs in some abundance near Walker's Ranch on Section 4, Block 109. It usually is found in minute seams, although in places masses several inches thick were noted. It was seen at the Johnson; Kyle; Michigan; Cooksey; Section 4, Block 109; Section 9, Block 109; Section 10, Block 109.

6...Last we can distinguish a cream-colored massive or kaolin-like sulphur. This occurs only rarely, but is present in some quantity at the Michigan. It there forms masses or layers up to several inches in thickness. This type was seen only at the Michigan and the Grant properties.

Kinds of Matrix Containing Sulphur.

The surface of this district may be said to be almost everywhere covered with gypsite or gypsiferous earth. This surface material in part represents the weathered remnant of the original sediments of gypsum, limestone, and dolomite or conglomerate, constituting the mantle rock and the bed rock of the region. In fact, in various places it can be traced, grading into

pure gypsum and limestone, and into brown earthy, siliceous material, evidently derived from the bedrock.

Gypsite consists of gray brown to dirty gray soil, usually unconsolidated at the surface, but fairly compact at a shallow depth. Flint pebbles are spread over practically the entire area, and locally there are layers of conglomerate consisting of flint or dolomite pebbles, or of the two combined. In places, considerable quantities of sulphur are contained in this superficial material, but it usually is not as rich in sulphur as the underlying materials to which it gives way when followed downward.

Over the entire district, with the possible exceptions of the extreme northwest and southeast extensions of the field, we find a *brown, siliceous material* underlying the gypsite veneer. By analysis this has been found to consist almost entirely of silica, but in places it contains also much selenite. It grades downward into a dark gypsiferous, cavernous and porous ground In places, these two materials are very much intermixed. This deeper-lying brown material is conglomeratic in places, with usually flint pebbles or pebbles which probably were originally limestone, but now consist of gypsum or even of siliceous material. This soft ground contains much sulphur, both massive and crystalline, the crystallized sulphur being usually well disseminated in all cavities.

A *dark ground* is present all over the district usually underlying the brown material. It possesses many characteristics in common with the brown ground, but it contains much more gypsum than the brown ground and it is less porous. It is typically a dark gray to black, compact earth, quite frequently porous, and even cavernous; containing an abundance of gypsum; both in the form of gypsite and selenite. It is very frequently conglomeratic, and contains beds or patches of dolomite and altered conglomerate, the altered pebbles probably having been limestone, now altered to gypsite. Much sulphur is present in this material, both massive and crystalline. More sulphur of massive texture occurs in this material than is found in the overlying brown ground. Crystallized sulphur is, as a rule, not so generally distributed in this ground.

Where the gypsum of the bed rock outcrops and has not been badly weathered, it consists of massive white alabaster. This holds true everywhere with the exception of the extreme western belt, where the gypsum is divided into thin layers by limy, bituminous partings. Both crystallized and massive sulphur occurs in this alabaster, but where seen, the occurrences were of no importance.

The accompanying table has been prepared to more clearly elucidate the relations noted in the distribution of different forms of sulphur to different types of rock and ground in which the sulphur is lodged.

TABLE SHOWING, IN NUMBER OF TIMES OBSERVED IN THE FIELD, THE FREQUENCY OF ASSOCIATION OF DIFFERENT TYPES OF SULPHUR WITH DIFFERENT KINDS OF MATRIX IN WHICH THE SULPHUR OCCURS.

Types of sulphur	Kinds of Matrix			
	Gypsite	Brown siliceous material	Dark gypsiferous, porous material	Massive gypsum
Yellow, crystallized sulphur	8	2	4	2
Yellow, massive sulphur	16	7	3	1
Green, crystallized sulphur		4	4	
Green, massive sulphur		2	1	
Silvery white, massive sulphur		7		
Cream white, massive sulphur			3	

Chemical Composition of the Sulphur and of Its Matrices.

Sulphur Analyses.

The amount of time available for field work in this district did not permit of a thorough sampling of the deposits. However, a number of samples were taken in order to obtain a general idea of how much sulphur the better grades of the material carried. The analyses of these samples for sulphur are given below. Three of the samples were tested qualitatively, for arsenic, with negative results. These analyses show variations between wide limits, and it is to be expected that the individual deposits will vary in the same manner. It seems that all of the localities contain some rich pockets.

ANALYSES OF SAMPLES OF MEDIUM AND HIGH GRADE SULPHUR ORE, FROM THE RUSTLER SPRINGS SULPHUR FIELD.

Analyses by J. E. Stullken.

Sample number	Sulphur* content in per cent	Arsenic (Qualitative test)
1	54.00	Not tested
2	40.50	Not tested
3	74.90	Not tested
4	15.80	Not tested
5	14.00	Not tested
6	48.70	Not tested
7	20.70	None
8	12.70	Not tested
9	51.40	None
10	10.10	Not tested
11	41.40	Not tested
12	36.80	Not tested
13	41.80	Not tested
14	30.10	Not tested
15	3.20	Not tested
16	90.40	Not tested
17	79.20	None
18	20.40	Not tested

*Sulphur extracted with carbon bisulphide.

LIST OF SAMPLES.

1. Picked sample of drab brown, irregularly thin-banded, clay-like sulphur from the Johnson Prospect.
2. Picked sample of brown, earthy material from the main exposure at the Kyle Prospect.
3. Picked sample of yellow conglomeratic material from the main exposure at the Kyle Prospect.
4. Black gypsiferous material from the dump at pit No. 5 on the Spann-Felch Holdings.
5. Dark gypsiferous conglomeratic material from beneath the hard conglomerate layer on the north side of 8 (see sketch map) Michigan Sulphur and Oil Company.
6. Picked sample of dark gypsiferous material from above the hard conglomerate layer mentioned under sample No. 5.
7. Mixed brown and black conglomeratic material from the southwest corner of 8 (see sketch map). Some of the black material contains metallic sulphides. From the Michigan Sulphur and Oil Company.
8. Altered conglomerate from the north side of locality 8, marked on sketch map of the Michigan Sulphur and Oil Company property.
9. Picked sample of black gypsiferous material from locality 16, marked on sketch map of Michigan Sulphur and Oil Company property. Contains cream-colored or kaolin-like and greenish yellow crystallized sulphur.
10. Brown earthy material overlying the material of sample No. 9.
11. Picked sample of brown earthy and black conglomeratic material from locality marked 13 on sketch map of Michigan Sulphur and Oil Company property.
12. Picked sample of gypsite from the Georgetown Prospect.
13. Picked sample of brown earthy siliceous material from the main exposure at the Cooksey Prospect.
14. Black banded gypsiferous material from the Cooksey Prospect.
15. Yellow incrustation now being deposited at Stinking Seep.
16. Picked sample of sulphur from near Walker's Ranch, probably in the southwest corner of Section 4, Block 109.
17. Sample of massive sulphur from the east side of the east hill, Grant Mines Property.
18. Sample of gypsite from the University lands.

Analyses were also made of several of the typical materials, with which the sulphur is associated. In the table below these analyses are brought together to facilitate comparison. These analyses show that the various deposits exerting, possibly, a se-

lective action on the deposition of sulphur, may be roughly divided into three classes; siliceous deposits, gypsiferous deposits, and deposits containing much bauxite. However, no hard and fast line can be drawn between the three classes. They grade one into the other. This is to be expected, as their composition depends both upon the nature of the original sediments and the degree of alteration to which they have been subjected by the processes resulting in deposition of the sulphur.

MINERAL ANALYSES OF SULPHUR BEARING DEPOSITS FROM THE RUSTLER SPRINGS SULPHUR FIELD.

J. E. Stulliken, Analyst.

	a	b	c	(d)	e	f
Silica	2.34	10.66	34.54	37.20	8.60	49.34
Ferric oxide	0.15	0.08	11.44	0.27	0.32	0.16
Alumina	1.95	33.48	16 69	1.63	11.28	0.18
Titanic oxide	------	------	6.67	------	------	------
Phosphorus pentoxide	------	------	Trace	Trace	------	------
Lime	31.72	2.50	6.76	19.76	5.72	1.35
Magnesia	0.36	0.34	1.01	0.51	0.30	0.32
Sulphur trioxide	28.87	------	5.08	30.59	19.23	------
Sulphur, free	3.16	13.35	1.76	1.00	22.00	46.00
Sodium oxide	4.89	6.14	0.76	0.34	1.21	------
Potassium oxide	0.08	0.19	1.16	0.34	1 37	------
Moisture	10.10	2.00	9.28	7.64	10.06	2.30
Loss on ignition	16.04	31.25	10.56	1.40	20.14	0.86
Total	99.66	99.99	99.53	100.68	100.21	100.51
Bauxite present		42.23		None	7.05	None

(a) Drab-colored porous rock containing much selenite. From the center of Section 34, Block 70. Sample taken by Dr. J. A. Udden.
(b) Pure white clay like material containing considerable gypsum. From the southeast corner of Section 13, Block 70. Sample taken by Dr. J. A. Udden.
(c) Clay from the southeast corner of Section 13, Block 70. Sample taken by J. A. Martin, Jr., Toyah, Texas.
(d) Siliceous gypsite. Typical rock from the Johnson Prospect.
(e) Dark gypsiferous and conglomeratic material from beneath the hard conglomerate layer on the north side of locality marked 8 on the sketch map of the Michigan Sulphur and Oil Company property.
(f) Typical brown earthy material from the main exposure at the Cooksey Prospect.

PROBABLE ORIGIN OF THE SULPHUR.

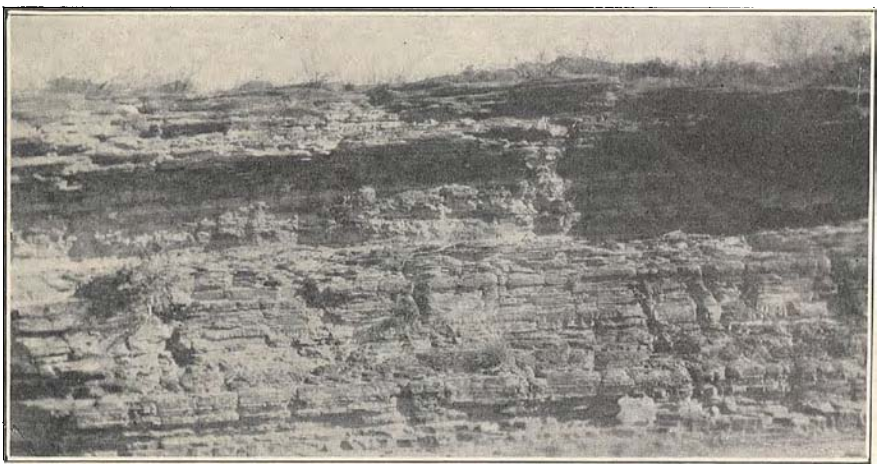
The facts that hydrogen sulphide gas is encountered all over this area, that sulphur is being deposited at the present time from the oxidation of this gas in solution or otherwise, and that much of the crystallized sulphur, judging by its location, must have been deposited by gases; lead one to believe that this mode of deposition was of considerable, if not of primary, importance in forming this deposit. The deposition of sulphur from this source seems to have depended largely upon the porosity of the inclosing material. It has been proved by Winogradsky that there are bacteria possessing the power to oxidize hydrogen sulphide to form sulphur.* Some of the sulphur, notably the light yellow kaolin-like variety, may be due to the deposition of colloidal sulphur from solution, since it has been proved that this can take place.**

It is not a very easy matter, however, to say just what is the ultimate source of the hydrogen sulphide. There are no evidences of volcanic disturbances in this district, and the nearest volcanic rocks are some forty miles distant, so it is not believed that the gases are due to dying vulcanism. Some of the sulphur may be formed by the action of hydrogen sulphide on calcium carbonate, which also produces gypsum. Some of the conglomerate beds, the pebbles in which were undoubtedly once carbonates, now altered to gypsum and containing sulphur, in places perhaps as replacements, lend some force to this view.

From the close association here of sulphur, gypsum, oil or bituminous material, it would seem possible, as advocated by most authors, that the sulphur has been formed from the reduction of gypsum by organic acids, but for the fact that this reaction, with one exception, has never been satisfactorily demonstrated in the laboratory under conditions approximating those obtaining in the field. The one exception noted was an experiment made by Hoppe-Seyler in 1886, using methane as the

*The Origin of Sulphur Deposits, by O. Stutzer, translated by W. C. Phalen, Economic Geology, Vol. 7, No. 8, p. 742.

**U. S. Geol. Surv., Bull 530: "Two Sulphur Deposits in Mineral County, Colorado", by Esper S. Larsen and J. Fred Hunter; pp. 363-369.



a. Cliff on Delaware Creek, about one mile east of Delaware Springs. May represent the transition beds between the Delaware and the Castile Formation. Alternating limy and shaly beds down to yellow sandstone at the water's edge. There are some 20 feet of finely banded limestone at the top.

b. Typical plain of the Delaware Formation. Looking east from the top of a limestone-capped sandstone mesa. Edge of mesa shows in the foreground.

reducing agent. However, it has been shown that this reducing action readily takes place under bacterial influence.* It would be practically impossible, without extensive researches, to say just what part the reduction of gypsum, either with or without bacterial influence, has played in the formation of the sulphur.

A study of the log of the Troxel well shows that pyrite is abundant almost from the top to the bottom, while bituminous material is present quite frequently from 680 feet to the bottom of the well. Now, hydrogen sulphide may be formed both from the oxidation of pyrite and the decomposition of organic material. Judging from the Troxel well section, there must be considerable quantities of both materials in the Castile Gypsum and in the upper part of the Delaware Mountain formation, and the hydrogen sulphide may have been derived from either one or both of these sources. Judging, however, from the fact that the pyrite is usually unaltered, and that the organic material has been altered, either in situ or at greater depths, as the presence of oil indicates, it seems more reasonable to suppose that at least the greater part of the hydrogen sulphide has been and is being derived from organic material.

The physical nature of the beds, through which the hydrogen sulphide had to pass, certainly exerted considerable influence on the deposition of the sulphur. It is possible that those beds lending themselves most readily to alteration now contain the bulk of the sulphur. The sulphur dioxide noticeable in a number of places is probably due to the oxidation of the sulphur.

There are other ways in which sulphur may be formed, but it is not believed that they were of sufficient importance to be considered here.

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*The Origin of Sulphur Deposits. O. Stutzer, translated by W. C Phalen, Economic Geology, Vol. 7, No. 8, p. 738.

DEVELOPMENT.

It is not known at exactly what date work started in this district, but considerable prospecting had been done prior to Dr. Smith's trip there in 1896. Much of the work spoken of in the older reports is inaccessible now, due to caving of the ground; and the sulphur piles, formerly present around some of the pits, have either been washed away or have been oxidized to the gaseous state. Considerable work has been done in this district in the last two years. This later work has been more extensive and deeper than anything done in the past.

Many considerations enter into a discussion of the commercial possibilities of these deposits. The district is still in the prospect stage, but what has been shown up is sufficient to justify further investigation and development. Just how deep the deposits extend it is at present impossible to say. The deepest workings in the district extend down about 43 feet. There is good sulphur at the bottom of this deepest excavation and it probably continues for some distance further down. The only way to ascertain to what depth the deposits extend is to deepen the workings or to drill.

It may be of some interest in this connection to mention the fact that two wells drilled in the spring of 1916 by the Calumet and Arizona Mining Company on their property about 12 miles northeast of Fort Stockton in Pecos County, showed much disseminated sulphur in gypsum down to a depth of 550 feet. Cuttings from these borings have been examined by Prof. C. L. Baker from whom the information has been obtained. These two borings are close together at a point where some fourteen years ago another boring was made to the depth of 1200 feet. In this boring considerable sulphur was encountered at depths between 200 and 600 feet below the surface.* These borings were made at a point 90 miles southeast from the sulphur fields in Culberson County. The finding of deep sulphur at this distance has, of course, no direct bearing on the depth to which

*University Mineral Survey Bulletin 9, November, 1904, p. 65. "Reconnaissance in Trans-Pecos Texas", by G. B. Richardson

sulphur may extend in Culberson County, but the circumstances of accumulation of sulphur in both of these places are probably related. We have at Fort Stockton, underlying the Comanchean, Permian rocks which are not far from being of the same age as the underlying formations in Culberson County. The source of the sulphur is probably some deeper underlying beds in both localities, as in many cases there is nothing on the surface to indicate the presence of the sulphur below.

Sulphur is such a low priced commodity that a considerable tonnage should be blocked out before any attempt is made to extract and market the product. This does not mean that a great deal of experimenting should not also be done in order to try to improve the present method of steam extraction. This process probably does not extract more than two-thirds of the contained sulphur.* As the deposits lie quite close to the surface, the mining of the sulphur-bearing rock can be done very cheaply.

Good water is very scarce in this region. A limited supply of water rather highly charged with mineral salts can be obtained by drilling in various places, mostly in the beds of gypsum in the draws.

There is no permanent fuel supply in the country. Local groves of juniper would furnish fuel for a limited period. Coal will sooner or later have to be imported. The cost of this coal at any of the properties east of the Rustler Hills would range from about $4.50 to $7.00 a ton, depending upon the quality. Up to date, only limited quantities of oil have been found in this region and it cannot be counted upon for fuel.

The distance from the nearest railroad is considerable, and it would not be feasible to build a branch line to the deposits, unless production on a very large scale was contemplated, because the sulphur would constitute practically all of the outgoing freight.

With some work, the wagon roads can be kept in fair condition, except when it rains, and motor trucks and trailers may be profitably used.

After the war, the price of sulphur will probably drop to

*E. G. Woodruff, U. S. Geol. Surv. Bull. 380, pp. 373-380.

somewhere near that point which it occupied before the war, and this fact should be remembered in considering future development.

It is hardly possible that the Culberson County sulphur can compete in the eastern market with the Louisiana-Texas coastal deposits, and thus it appears probable that a western market will have to be found for any sulphur produced in West Texas. If one company could acquire control of several of the properties on which some development has been done, their chances of success would be much better than the chances of smaller companies operating independently.

In conclusion, I may say that in my judgment it will take the most economical and intelligent working and it will also require considerable capital to place any of these properties on a paying basis.

WATER RESOURCES.

Water is scarce in the entire field, and little has as yet been done to develop what water resources there may be in existence. Natural underground waters are to be expected to be highly mineralized. Even surface waters, except after heavy rains, are high in solvent solids. For dscussion of earlier observations on this subject, the reader is referred to G. B. Richardson's Report of a Reconnaissance in Trans-Pecos Texas, Bulletin of the University of Texas No. 23. The following analyses show the quality of some samples of water collected in that region recently. The ground waters contain more than twice the amount of solids found in the already highly concentrated surface waters in these analyses.

(Determinations given in parts per million)

Ions determined	1	2	3	4	5
Calcium	978	974	1263	1148	1884
Magnesium	259	168	303	604	384
Sodium and potassium (calculated as Sodium)	2025	2530	5990	8540	8538
Sulphate radicle	2645	2563	3039	3360	3886
Bicarbonate radicle	106	117	451	398	307
Chloride radicle	3590	4150	9825	13780	13651
Sulphur as Hydrogen Sulphide	32	None	92	65	None
Total dissolved solids (Dried 1 hr. at 180° C)	10054	10538	21182	27813	28008

1..From head of draw east of Lindsey's property. (Anal. 3137).
2..Running water in creek northwest of Maverick Spring, Culberson County, collected by W. B. Phillips, Oct. 16, 1916. (Anal. 3138).
3..Water from a big deep pool in draw near road to W. B. Hicks' house, collected by W. B. Phillips, Nov. 17, 1916. (Anal. 3134).
4..Water from seep below Maverick Spring; collected by W. B. Phillips, Nov. 17, 1916. (Anal. 3135).
5..Water from a well in northwest part of Sec. 1, Block 111, Culberson County, at depth of 23 ft. Collected by W. B. Phillips, Dec. 1, 1916. (Anla. 3143).

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Map Showing Locations of the Rutler Springs Sulphur Deposits

Properties visited.

1....Pit in center of Section 34, Block 70.
2....Pit in southeast corner of Section 13, Block 70.
3....The Johnson Prospect.
4....The Kyle Prospects.
5....Open cut on Section 14, Block 113.
6....The Dot Prospect.
7....The Spann-Felch Holdings.
8....The Holdings and Works of the Michigan Sulphur and Oil Company.
9....The Georgetown Prospect.
10....The Stinking Seep Prospect.
12 15..Deposits near Walker's Ranch: (12) Section 4, Block 109; (13) Section 4, Block 109; (14) Section 9, Block 109; (15) Section 10, Block 109.
1....Deposits on and near the University Land.
1....The Grant Mines Property and Vicinity.
18....Open Cut on Section 8, Block 61.

Properties not visited.

A. The Luckett Property.
B. The Wildcat Prospect.
C. The Pat, Lone Wolf, and Golson Prospects.
D. The Edwards Property.
E. The Maracopa Prospect.
F. The Toyah Sulphur Company of Louisiana.